Condition of Wetlands in the Mispillion River Watershed

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Delaware Department of Natural Resources and Environmental Control

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Kenneth E. Smith
Alison B. Rogerson
Andrew M. Howard
Brittany L. Haywood

Delaware Department of Natural Resources and Environmental Control
Division of Watershed Stewardship
100 W. Water St., Suite 10 B
Dover, DE 19904

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EXECUTIVE SUMMARY

The Delaware Department of Natural Resources and Environmental Control (DNREC) documented wetland acreage trends and determined the ambient condition of wetland resources in the Mispillion and Cedar Creek River Watersheds (Mispillion) in 2012. The goal of this project was to summarize recent gains and losses in wetland acreage, assess the condition of tidal and non-tidal wetlands throughout the watershed, and identify prevalent wetland stressors. Based on findings we make watershed-specific management recommendations to improve wetland restoration and protection, and educate landowners on watershed stewardship and the importance of wetland conservation for their health and well-being.

The Mispillion River watershed is located in southeastern Kent County and northeastern Sussex County where it encompasses 128 square miles (33,500ha) of the Delaware Bay and Estuary Basin. The Mispillion watershed consists of the Cedar Creek and Mispillion River sub-watersheds which were combined for this project and report. The Mispillion River originates southwest of Milford and flows approximately 20 miles (32km) eastward dividing Kent and Sussex County through Houston and Milford. Cedar Creek flows for approximately 15 miles (24km) through Lincoln and Slaughter Beach. Both water bodies meet before flowing into the Delaware Bay through the Mispillion Inlet. Approximately 25% of the watershed (21,000ac) is covered by wetlands, including tidal estuarine wetlands (51%), non-tidal headwater forested flats (27%), riverine (14%), and depression wetlands (7%; State of Delaware 2012).

We estimated historic and recent wetland losses in the watershed based on historic hydric soil maps and previous wetland mapping efforts. Our comparison indicated that by 1992, approximately 19% (4,400ac) of the watershed's wetlands that persisted at the time of settlement had been filled or lost due mostly to conversion into agricultural land, and residential and commercial development. Between 1992 and 2007 the watershed lost another 38 acres of wetlands while gaining approximately 75 acres of wetlands with the majority being retention or storm water ponds. As a result of recent development in the Milford area nontidal wetlands were lost and replaced with lower functioning storm water retention ponds. Two-thirds of tidal wetlands lost during this period were located behind the beach front dunes along the Delaware Bay shoreline of the Mispillion River watershed. These wetlands have now become the beach front due the migration of the shoreline landward or have been converted to submerged, open water habitat.

To assess wetland condition and identify stressors affecting wetland health, we conducted rapid assessments at random wetland sites throughout the watershed. Wetland assessments were performed in 34 tidal wetlands using the Mid-Atlantic Tidal Rapid Assessment Method (MidTRAM) Version 3.0. In addition, 33 freshwater riverine wetlands, 45 headwater forested flat wetlands, and one isolated depression wetland were visited and assessed using the Delaware Rapid Assessment Procedure (DERAP) Version 6.0. Wetland assessment sites were located on public and private property and randomly selected utilizing a probabilistic sampling design with the assistance of the Environmental Protection Agency's Ecological Monitoring and Assessment Program.

Estuarine wetlands in the Mispillion watershed were primarily located on the east side of Route 1 inland of the Delaware Bay along the Mispillion River and Cedar Creek waterways and tributaries. Estuarine wetlands comprised more than half the wetlands in the Mispillion watershed, with an average condition score of 74.3, ranging from 48 to 84 on a scale that ranges from 0-100. Estuarine wetlands in the Mispillion River watershed had low impacts due to diking or restriction of tidal flow, and point source discharges into sampled wetlands were not found. Using condition categories that rank stress level in wetlands to separate the tidal wetland population 18% were considered to be minimally or not stressed, 76% were moderately stressed, and 6% were severely stressed. Two influences that negatively affect tidal wetland scores were the high prevalence of invasive plants (e.g. *Phragmites*) and wetland perimeter obstructions that could prevent wetlands migrating (e.g. bulkhead, roads).

Freshwater wetlands, which made up just less than half of the watershed's wetland population, were sampled in similar fashion. The three most common types of freshwater wetlands were sampled: headwater flats, floodplain riverine wetlands, and isolated depressions. Forested headwater flat wetlands were dispersed throughout the watershed and made up 27% of the watershed's wetland population. Most flats are found in the headwaters of streams as low-lying forested areas. On the Index of Wetland Condition, flats scored an average of 76.5, ranging from 41 to 95. Of the 45 sites assessed, 15% were severely stressed, while 27% were minimally stressed, and 58% were moderately stressed. Common stressors for flat wetlands of the Mispillion watershed included ditching and invasive plants.

Riverine wetlands ran along the upper portions of the Mispillion River and Cedar Creek generally west of Route 1, including the smaller tributaries that lead to headwater areas. Riverine wetlands comprised 15% of the watershed's wetlands with about 3,500 acres throughout the watershed. Riverine wetlands provide vital flood storage and valuable habitat corridors for plants and wildlife. We summarized the stress levels of riverine wetlands based on 33 sites, and report that 15% of riverine wetlands were minimally or not stressed, 61% were moderately stressed, and 24% were severely stressed. The ability of riverine wetlands to function fully was most impacted indirectly by the presence of adjacent agriculture and development. The frequency of invasive plant colonization among riverine wetlands was indicative of disturbances to soil and/or hydrology.

Compared to five other watersheds previously assessed in Delaware, the wetlands of the Mispillion watershed were in similar condition to the nearby Broadkill watershed. Similar land use patterns and sources of impacts have resulted in the majority of the wetland population (65%) being moderately stressed. One quarter of wetlands in this watershed are healthy and functioning well but 12% are severely impacted. Wetlands in healthy condition should be protected whereas areas with many impacts present an opportunity for restoration and improvement.

INTRODUCTION

Wetlands provide many benefits to the residents and visitors by: providing habitat for plants and animals, minimizing flooding, controlling erosion, and improving water quality. Wetlands remove and retain disturbed sediment s, pollutants and nutrient runoff from non-point sources such as agriculture, land clearing, and construction before they enter our waterways. They also have significant cultural and economic value as a source of recreation (e.g. hunting, fishing, and birding) and livelihood (e.g. fishing, crabbing, fur-bearer trapping). Salt water wetlands are biologically rich habitats and are a critical resource for migrating shorebirds and wintering waterfowl, and serve as nurseries for commercial fish and shellfish species (Figure 1). Freshwater wetlands collect and slowly release storm water that spills over channel banks, while also providing habitat for many species of native plants and animals (Figures 2 and 3).

Figure 1. A tidal emergent wetland in the Mispillion River watershed.

Figure 2. A forested headwater flat wetland in the Mispillion river watershed.

Wetlands have a rich history across the region and their aesthetics have become the symbol of the Delaware coast. The State of Delaware is dedicated to improving wetlands through restoration, protection, education, and effective planning to ensure that they will continue to provide these important services to the citizens of Delaware (DNREC 2015). Between 1992 and 2007 nearly 3,900 acres of vegetated wetlands were lost through conversion to another land use, while 768 acres of vegetated wetlands were created or restored. These changes resulted in a net loss of 3,126 acres of vegetated wetlands (Tiner 2011). In addition to assessing changes in wetland acreage over time, monitoring wetland condition and functional capacity is necessary to guide management and protection efforts.

Figure 3. A riverine wetland in the Mispillion watershed.

Since 1999 DNREC has been developing and refining a wetland assessment and monitoring program to evaluate the health of wetlands. The program evaluates wetland health, or condition, and documents the presence and severity of stressors that are degrading wetlands and preventing them from functioning at their full potential on a watershed scale. Useful information and recommendations can be used by watershed organizations, state planning and regulatory agencies, and other stakeholders to improve wetland restoration and protection efforts. Protection efforts through acquisition or easements can be directed towards wetland types in good condition, allowing restoration efforts to target altered and degraded wetland types to increase functions and services. Wetland assessment information identifies specific stressors that are impacting wetlands, and can direct voluntary restoration projects and set priorities.

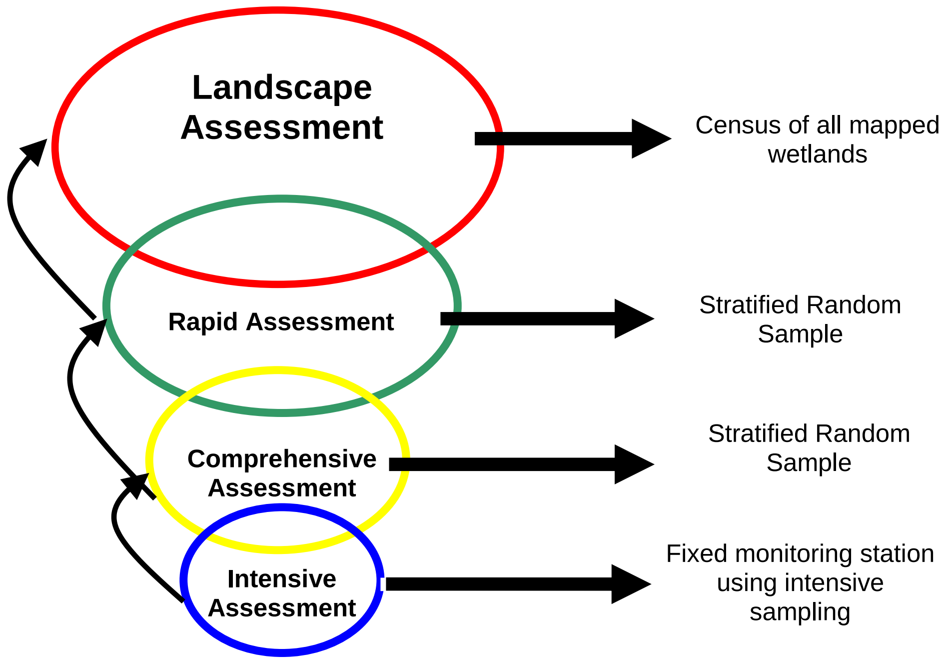
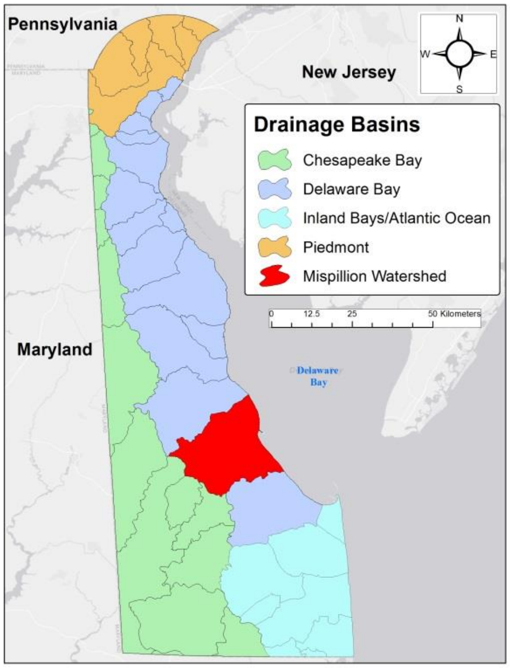


Figure 4. The multi-tiered approach to evaluating wetlands.

DNREC's Wetland Monitoring and Assessment Program have been developing scientifically robust methods using the Environmental Protection Agency (EPA) approved 4-tiered approach to evaluate and monitor wetlands across the Mid-Atlantic region by examining wetlands from the landscape level to site-specific studies (Figure 4). Three of these four tiers consist of active wetland monitoring—rapid assessment methods (Tier 2), comprehensive assessment methods (Tier 3), and intensive monitoring (Tier 4). DNREC and its partners have developed, and continue to refine, scientifically valid methods to assess the condition of wetlands on a watershed basis. These methods are used to generate an overall evaluation of the ambient condition of wetlands in a watershed, as well as to identify common stressors by wetland type and provide management recommendations. In this report, we review the changes in wetland acreage and highlight the potential resulting changes in wetland function, summarize the condition of tidal and freshwater wetlands, identify common stressors impacting wetlands, and provide recommendations for improving the wetlands of the Mispillion River and Cedar Creek watersheds.

Watershed Overview



Map 1. Location of the Mispillion River Watershed and the major basins of Delaware. Watersheds at the Hydrologic Unit Code 10 scale are outlined in gray.

The Mispillion River watershed drains water collected from both Kent and Sussex Counties via the Mispillion River and Cedar Creek. The Mispillion watershed is one of 16 watersheds in the Delaware Bay and Estuary Basin (Map 1). The Mispillion watershed is bordered by the Murderkill River watershed to the north, the Broadkill River watershed to the south, and the west borders three Chesapeake Bay Basin watersheds: the Nanticoke River, Gum Branch, and Gravelly Branch watersheds. The Mispillion watershed covers almost 33,500ha (83,000ac) and is primarily comprised of agriculture and urban development with isolated patches of forest and wetlands. The Mispillion River originates southwest of Milford and flows approximately 20 miles (32 km) eastward dividing Kent and Sussex Counties. Cedar Creek flows for approximately 15 miles (24km) eastward to meet with the Mispillion River before it outlets into the Delaware Bay through the Mispillion Inlet. The Mispillion watershed has a series of manmade ponds that feed into each other through dams from the west which eventually merge with the Mispillion River beginning with Blairs Pond then traveling east into Griffith and Haven Lakes, where it enters Silver Lake (Map 2). When the water enters Silver Lake it converges with the Mispillion River. The watershed is also dotted with about 1,500 acres of many other small lakes, ponds, creeks, and rivers.

Geology and Hydrogeomorphology

The Mispillion watershed is contained within the Atlantic Coastal Plain Physiographic Province just south of the Appalachian Piedmont Fall Zone. Most of present day Delaware was covered by ocean before the last ice age where large amounts of sediments from the ancient Appalachians were carried down the Delaware River, Susquehanna River and others, and settled onto the coastal plains of Delmarva (DNREC 2005). Repeated continental glacier advances and retreats helped to shape the relative sea level of the area as well as dictate stream formations (NERRS 2009).

The hydrogeomorphology of the region contains 3 of the 4 hydrogeomorphic regions found in the Atlantic Coastal Plain Physiographic Province; 1) beaches and tidal marshes located on the east side of the watershed adjacent to the Delaware Bay, 2) poorly drained uplands located in the northeastern corner of the watershed, and 3) well drained uplands located throughout the watershed (DNREC 2005).

Wetlands in the northeastern part of the watershed are poorly drained and consist mostly of headwater flat wetlands, while riverine wetlands flank the Mispillion River and Cedar Creek in the adjacent floodplains. Estuarine wetlands are found mostly in the regions east of Route 1 near the Delaware Bay.

The unconfined aquifer (water table) and several deeper confined aquifers throughout the Delaware Bay and Estuary area support the ground water for the basin (DNREC 2005). The unconfined aquifer flows through gravelly sands and is recharged or refilled by precipitation in areas where permeable sediments allow water to infiltrate down to the aquifer. These aquifers are the source of potable water in the Mispillion Watershed and are heavily drawn upon for agricultural, industrial and municipal uses.

Watershed History and Land Use

The Mispillion River is well known for its history in ship building; at one time there were 6 different producers stationed on the river. The ship building industry lasted until the early 1900's when the last giant white oaks were chopped down. Milford is positioned along the Mispillion River and used the river as a resource to create a booming commercial center for the large local agricultural community when the ship building industry collapsed. Agriculture continues to be a mainstay in the watershed today even though overall acreage has decreased in the last fifteen years.

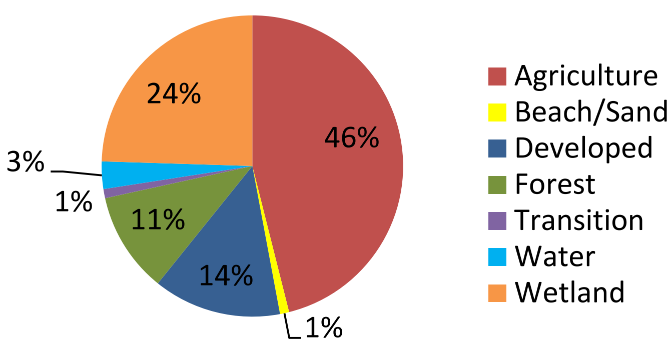


Figure 5. Proportion of 2012 land uses of the Mispillion River watershed.

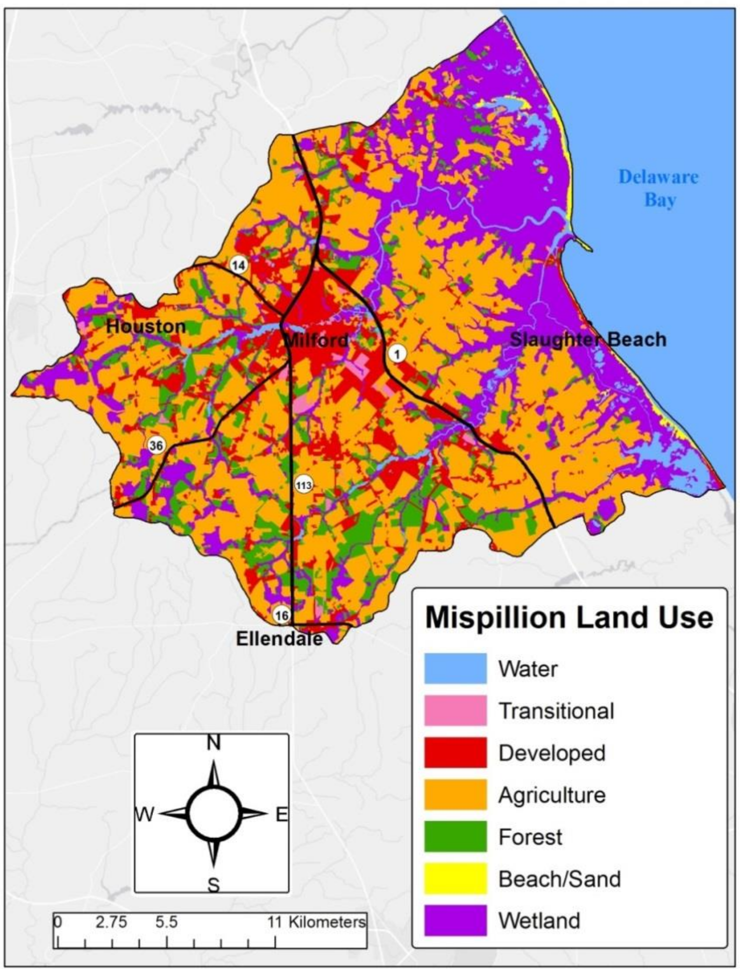
Land use in the Mispillion watershed is a mix of urban, suburban and natural areas. Based on 2012 National Land Cover Dataset (NLCD), 46% of the watershed is in agriculture which is a broad land use that encompasses row crops, nurseries, feedlots, and rangelands (Figure 5). Wetlands cover one quarter (25%) of the watershed, followed by developed (13%) and forest (10%; Figure 5).

In a comparison between land-use proportions in 1997 and 2012 several trends are evident. Between 1997 and 2012 the proportion of land in agricultural production decreased by 4.1% (Table 1). Historically agriculture was a dominant land use in the watershed, but recent declines were similar to trends across the state (5.5% or 56,400 acres). Similarly, forestland decreased in this 15- year timeframe by 3.5%. Conversely, development (residential, commercial and industrial) increased by 2.7% (Table 1). The majority of this development occurred in the Milford area and along the Route 1 corridor. Wetland acreage on the 2012 NLCD increased as well by 3.0% mostly due to the creation of storm water retention ponds and by some areas formerly categorized as forests being categorized more recently as forested wetlands.

Table 1. Land use cover and land cover change (1997 and 2012) in the Mispillion River Watershed based on Land-use/Land-cover datasets.

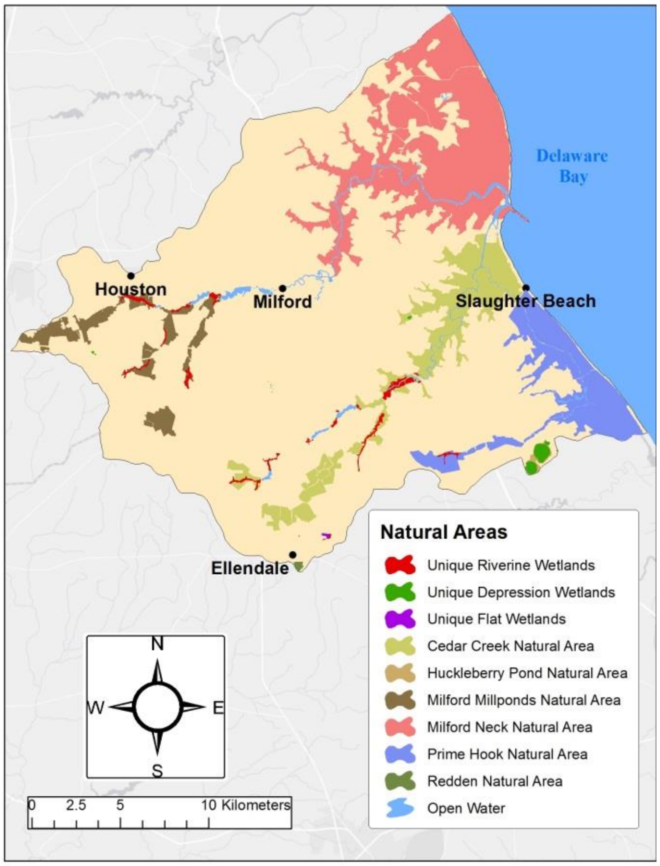
Land Use	1997 Land Use	2012 Land Use	97-12 Change
Agriculture	50.0%	45.9%	-4.1%
Forest	14.1%	10.6%	-3.5%
Developed	11.0%	13.7%	2.7%
Water	1.9%	3.4%	1.5%
Wetland	22.5%	25.6%	3.0%
Transitional	0.5%	0.9%	0.4%

Environmental contamination is an issue in the Mispillion River watershed; specifically low dissolved oxygen levels, high nutrient loads, and high bacteria levels have been the main problems. According to the watershed's pollution control strategy, the Mispillion River watershed has 12 bodies of water that have some kind of contamination and the state has created Total Maximum Daily Loads (TMDLs) to combat the problems (DNREC 2012). The concentration of animal production is high as well as some crop production. The runoff from concentrated areas of animal production contributes bacteria and nutrients to the water resources in this watershed (Tetra Tech 2006). The Mispillion River watershed has 2 permitted facilities for stormwater discharge into the watersheds, which are known as point sources. This is a source of historically high levels of nutrients and bacteria in the Mispillion River watershed (Tetra Tech 2006).



Map 2. Landuse patterns in the Mispillion River watershed in 2012.

The Mispillion watershed has 5 state and 1 federal wildlife natural areas covering 26% (21,000ac) of the watershed, with Milford Neck Natural Area being the largest tract with 8,131 acres (Map 2). Prime Hook National Wildlife Refuge consists of approximately 4,000 acres of wetlands and protected natural areas within the watershed but also includes another 4,500 acres just south of the watershed border. Prime Hook National Wildlife Refuge has been undergoing extensive management changes related to the health and future of the four wetland management units. Two management units have been estuarine impoundments with regular tidal influence. The other two were managed as freshwater impoundments but were recently converted to tidal estuarine areas after the Delaware Bay breached and created open breaks in the barrier dunes. The abrupt change in salinity in the impoundments caused a massive die off of the freshwater vegetation resulting in a conversion to open water. Major efforts to restore the impacted impoundments began in 2015 and will take several years to complete but should result in the creation of addition wetland habitat.

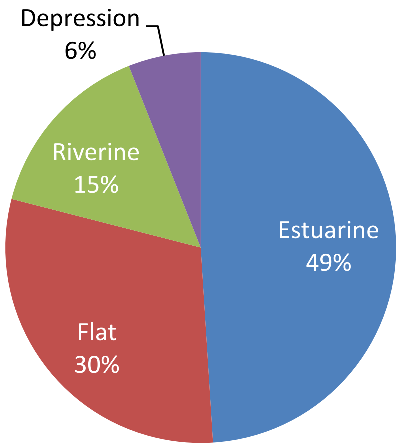


Map 3. Distribution of unique wetland and natural areas in the Mispillion River watershed, based on 2012 mapping.

The State of Delaware recently produced a document discussing sea level rise and its effects on Delaware (State of Delaware, 2012). Based on the most modest estimate for sea level rise (0.5m in 100 years), the bathtub model predicted that 9% of non-tidal wetlands and 98% of tidal wetlands will become inundated by the year 2100 (State of Delaware, 2012). The model spotlighted the critical need for coastlines to remain softened and natural to allow wetlands to migrate inland to higher elevations. Without this ability Delaware will witness extreme loss of tidal wetlands and coastal resources. In addition, rising sea levels will drive saltwater further upstream into freshwater habitats causing a major change in the habitat and plant community.

Wetland Resources

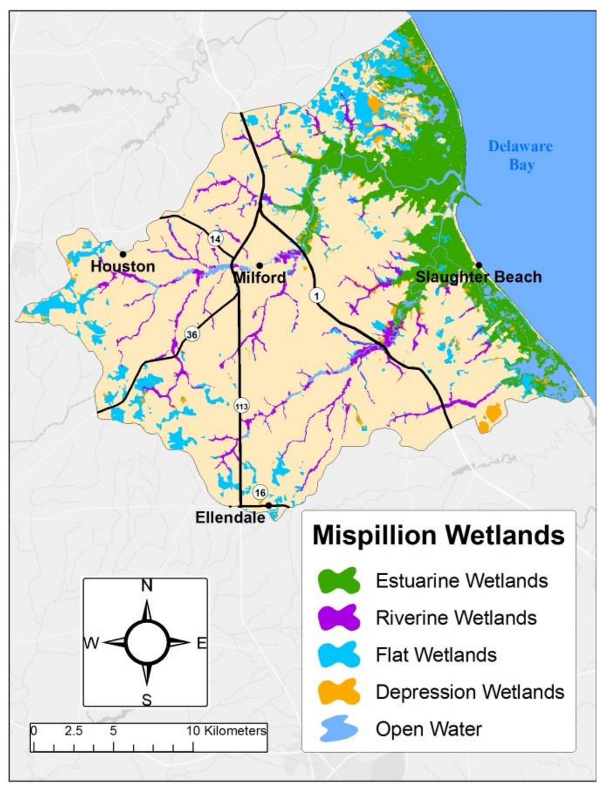
Wetlands comprised 25% of the land within the watershed with tidal estuarine wetlands being most abundant followed by headwater flats and riverine wetlands (Figure 6). Given the predominance of agriculture in the Mispillion watershed, wetlands play a key role in improving water quality, providing flood and erosion control, and providing vital habitat for wildlife. Wetlands improve water quality by trapping loose sediments and excess nutrients from runoff before they enter surface waters. Wetlands assist in flood and erosion control by securing banks with plant roots, absorbing wave energy, and soaking and holding flood waters. Wetlands are a key habitat for rare plant and wildlife species, create corridor habitat to encourage movement, and offer recreational opportunities for visitors to enjoy.



Wetland Type	Hectares (Acres)	Proportion
Estuarine	4,332 (10,704)	49
Flat	2,628 (6,493)	30
Riverine	1,277 (3,156)	15
Depression	563 (1,390)	6
Total	8,800 (21,743)	

Figure 6. Wetland acreage and proportion for each hydrogeomorphic wetland type in the Mispillion River watershed.

Salt water wetlands dominate the eastern portion of the watershed as the Mispillion River and Cedar Creek approach the Delaware Bay (Map 4). These wetlands were found on the coast and along the waterways upstream towards Route 1. Freshwater wetlands including flats, riverine, and depression wetlands are found throughout the watershed along the Mispillion River and Cedar Creek and their tributaries. Most of the flat wetlands were found in the northeastern and southwestern borders of the watershed. Riverine wetlands meandered along rivers and streams, connecting tidal wetlands with headwater flats. A small amount of isolated depression wetlands were scattered throughout.



Map 4. Distribution of wetlands in the Mispillion River Watershed, based on the 2012 mapping.

The Mispillion watershed contains 270 ha (675 ac) of unique wetland habitats, with 197 ha (487 ac) of Atlantic white cedar and 76 ha (188 ac) of Coastal Plain Pond habitat. These habitats are considered unique because they are key habitats for species of greatest conservation need outlined by the Delaware Wildlife Action Plan (DE DNREC 2006). The species of greatest conservation need could be state or federally endangered or threatened species. These habitats are known to be of some importance to these species, whether it is their year round habitat or a seasonal use such as the Red Knot which uses the Delaware Bay as a migratory stopover.

The Mispillion watershed is part of the Delaware Bay and Estuary Basin which was recognized by the

Ramsar Convention on Wetlands as one of the "international wetlands of importance" because of the role wetlands play in shorebird migration and waterfowl wintering grounds (Ramsar 2014). The Ramsar Convention is an intergovernmental treaty that provides the framework for the conservation and wise use of wetland and their uses, which allows them to designate wetlands as "of international importance". The Delaware Bay and Estuary Basin was also awarded in 1986 for being the first Western Hemisphere Shorebird Reserve Network (WHSRN) Site of Hemispheric Importance (WHSRN 2009). This is awarded to sites that are visited by 500,000 or more shorebirds a year, and which account for more than 30 percent of the biogeographic population for a species. The Mispillion Inlet is one of the key stopovers for shorebirds in the state such as red knot, ruddy turnstones, and sand pipers as they stop and feed on horseshoe crab eggs before they continue to fly north to summer breeding grounds.

METHODS

We documented the distribution of wetlands within the Mispillion River watershed and estimated the acreage of wetlands that have been lost, both recently and historically. Wetland condition assessments were completed in tidal and non-tidal wetlands in the Mispillion River watershed during the summer of 2012. We used a probabilistic survey approach to assess wetlands on both private and public property throughout the watershed. Tidal wetlands were assessed using the Mid-Atlantic Tidal Rapid Assessment Version 3.0 (MidTRAM; Jacobs *et al*. 2010), and non-tidal wetlands were evaluated with the Delaware Rapid Assessment Protocol Version 6.0 (DERAP; Jacobs 2010).

Changes to Wetland Acreage

We used Delaware wetland maps to determine the current distribution of wetlands across the Mispillion River watershed, as well as where wetland loss has occurred in recent decades and since colonization. Historic wetland acreage was estimated using a combination of current U.S. Department of Agriculture soil maps and historic soil survey maps from 1915. These maps are based on soil indicators such as drainage class, landform, and water flow. Hydric soils occurring in areas that are currently not classified as wetlands due to significant human impacts, either through urbanization, land clearing, or hydrologic alterations, are assumed to be historic wetlands that have been lost. Current acreage represents wetlands that were mapped in 2007 during Delaware's most recent statewide wetland mapping effort (SWMP 2007). Recent trends in wetland acreage were classified as wetlands 'lost', 'gained', or otherwise 'changed' during the 15-year period of 1992 and 2007 (State of Delaware 1994, Tiner *et al*. 2011).

Field Site Selection

Statistical survey methods developed by the U.S. Environmental Protection Agency's Ecological Monitoring and Assessment Program (EMAP) were used to extrapolate results from the sampled population of wetland sites to wetlands throughout the watershed. EMAP in Corvallis, Oregon assisted with selecting 250 potential sample sites in estuarine intertidal emergent wetlands and 500 potential sample sites in palustrine wetlands using a generalized random tessellation stratified design (Stevens and Olsen 1999, 2000). A target population was created from all vegetated wetlands from the 2007 state wetland maps. Study sites were randomly chosen points within mapped wetlands, with each point having an equal probability of being selected. Sites were considered and sampled in numeric order as dictated by the EMAP design - lowest to highest. Sites were only dropped from sampling if permission for access was denied, the site was inaccessible, the site was of the wrong wetland classification, or if the site was upland. The goal was to sample 30 tidal sites and 30 non-tidal sites in each common hydrogeomorphic (HGM) class (riverine, flats, and depression).

Data Collection

Landowner Contact and Site Access

We obtained landowner permission prior to assessing and sampling all sites. We identified landowners using county tax records and mailed each landowner a postcard providing a brief description of the study goals, sampling techniques, and contact information. If a contact number was available we followed the mailings with a phone call to discuss the site visit and secure permission. If permission was denied the site was dropped and not visited. Sites were deemed inaccessible if a landowner could not be identified or if the site was unsafe to visit.

Assessing Tidal Wetlands

We evaluated the condition of tidal wetlands using the MidTRAM v3.0 protocol. MidTRAM was designed and calibrated to assess polyhaline and mesohaline estuarine tidal wetlands and developed with pilot data from Delaware, Maryland, and Virginia. MidTRAM was created by adapting the New England Rapid Assessment Method (NERAM; Carullo *et al*. 2007) and the California Rapid Assessment Method (CRAM; Collins *et al*. 2008) and consists of 14 scored metrics that represent the condition of the wetland buffer, hydrology, and habitat characteristics (Table 2). MidTRAM uses a combination of qualitative evaluation and quantitative sampling to record the presence and severity of stressors in the field or in the office using maps and digital orthophotos.

MidTRAM was used to complete assessments at least the first 30 random points that we could access, and which met our criteria of being of an estuarine intertidal emergent wetland at least 0.1 acres in size. Prior to field assessments we produced site maps and calculated buffer metrics using ArcMap GIS software (ESRI, Redlands, CA, USA). The attributes measured included buffer width, surrounding development, percent of assessment area with a 5m buffer, 250m landscape condition, and barriers to landward migration (Table 2). All metrics measured in the office were field verified to confirm accuracy.

We navigated to the EMAP points with a handheld GPS unit and established an assessment area (AA) as a 50m radius circle (0.78 ha) centered on each random point (Figure 7). If a 50m radius circle more than 10% upland or open water habitat, we adjusted the circle the least distance necessary up to 50m as described in the protocol. We defined the AA buffer area as a 250m radius area around the AA.

Eight 1 m^2 subplots were established along two perpendicular 100 m transects that bisected the AA. These subplots were used to measure horizontal vegetative obstruction and soil bearing capacity (Table 2). We oriented one transect perpendicular to the nearest source of open water (>30m wide) and the other was perpendicular to the first. We placed subplots 25m and 50m from the center of the AA along each transect. Subplots were numbered clockwise starting with the plot 25m from the AA center point, followed by the 50m one towards open water (Figure 7). If a subplot fell in a habitat type or patch that was not characteristic of the site (e.g. in a ditch) we moved it the shortest distance possible along the transect to the nearest site representative of the site location.

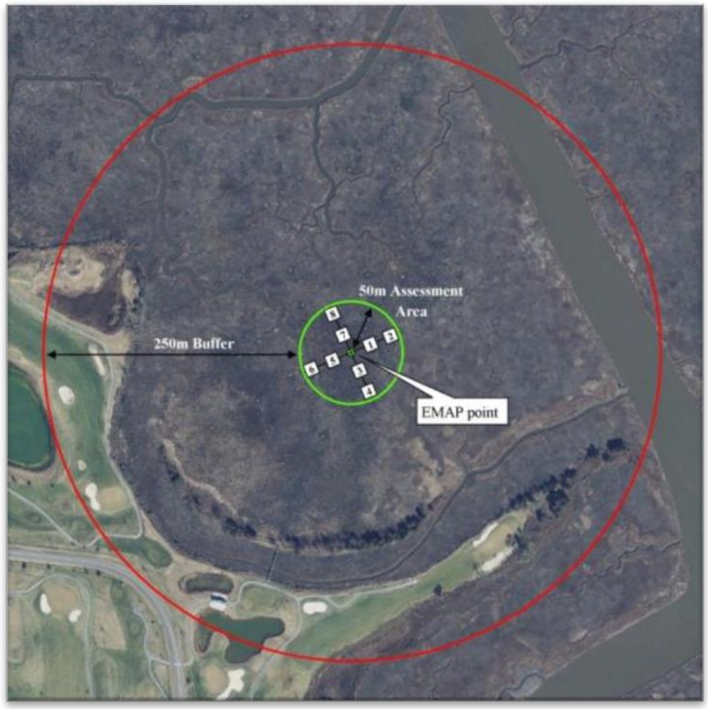


Figure 7. Standard assessment area, subplot locations, and buffer used to collect data for the Mid-Atlantic Tidal Rapid Assessment Method Version 3.0.

Sampling and data collection were completed as described in the MidTRAM v3.0 protocol. Assessment data collection was completed for all metrics within the AA and buffer via visual inspection during one field visit during the growing season (July 1-September 30). The average field time to sample each site was 2 hours, with an average of 0.5 hour needed to complete computer-based metrics. After completing the field assessments, the field crew assigned each site a Qualitative Disturbance Rating from 1 (least disturbed) to 6 (most disturbed) using best professional judgement (category descriptions can be found in Appendix A). A normalized final score was then computed, which provides a quantitative description of tidal wetland condition out of a total of 100 points. Detailed instructions for using MidTRAM are provided in the protocol (Jacobs et al. 2010).

Table 2. Metrics measured with the Mid-Atlantic Tidal Rapid Method Version 3.0.

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*	*Qualitative or Quantitative*
Buffer/Landscape	Percent of AA Perimeter with 5m-Buffer	Percent of AA perimeter that has at least 5m of natural or semi-natural condition land cover	Buffer	Quantitative (Office)
Buffer/Landscape	Average Buffer Width	The average buffer width surrounding the AA that is in natural or semi-natural condition	Buffer	Quantitative (Office)
Buffer/Landscape	Surrounding Development	Percent of developed land within 250m from the edge of the AA	Buffer	Quantitative (Office/Field)
Buffer/Landscape	250m Landscape Condition	Condition of surrounding landscape based on vegetation, soil compaction, and human visitation within 250m	Buffer	Quantitative (Office/Field)
Buffer/Landscape	Barriers to Landward Migration	Percent of landward perimeter of marsh within 250m with physical barriers preventing marsh migration inland	Buffer	Quantitative (Office/Field)
Hydrology	Ditching & Draining	The presence and functionality of ditches in the AA	AA	Qualitative (Field)
Hydrology	Fill & Fragmentation	The presence of fill or marsh fragmentation from anthropogenic sources in the AA	AA	Qualitative (Field)
Hydrology	Diking/Restriction	The presence of dikes or other restrictions altering the natural hydrology of the wetland	AA and Buffer	Qualitative (Field)

Table 2, continued:

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*	*Qualitative or Quantitative*
Hydrology	Point Sources	The presence of localized sources of pollution	AA and Buffer	Qualitative (Field)
Habitat	Bearing Capacity	Soil resistance using a slide hammer	AA subplots	Quantitative Field)
Habitat	Horizontal Vegetative Obstruction	The amount of visual obstruction due to vegetation	AA subplots	Qualitative (Field)
Habitat	Number of Plant Layers	Number of plant layers in AA based on plant height	AA	Qualitative (Field)
Habitat	Percent Co-dominant Invasive Species	Percent of co-dominant species that are invasive in the AA	AA	Qualitative (Field)
Habitat	Percent Invasive	Percent cover of invasive species in the AA	AA	Qualitative (Field)

Assessing Non-tidal Wetland Condition

Rapid Sampling in Non-tidal Wetlands

DERAP is used to assess the condition of non-tidal wetlands based on the presence and intensity of stressors related to habitat, hydrology, and buffer elements. DERAP scores are calibrated, separately for each HGM subclass, to comprehensive wetland condition data collected using the Delaware Comprehensive Assessment Procedure (DECAP; Jacobs et al. 2009). DERAP was followed to complete assessments at 45 headwater flats, 33 riverine, and 1 depression in the Mispillion River watershed in 2012.

Figure 8. Standard assessment area and buffer used to collect data for the Delaware Rapid Assessment Procedure Version 6.0.

We navigated to EMAP points with a handheld GPS unit and established an assessment area (AA) as a 40m radius circle (0.5ha) centered on each random point (Figure 8). If the 40m radius circle included >10% upland or open water, we moved the AA the least distance necessary (up to 40 m) or changed to a rectangle shape of equal area as described in the protocol. The entire AA was explored on foot and evidence of wetland stressors were documented (Table 3). Current and historic aerial photos were used to determine forestry activity and buffer stressors and then verified in the field. Similar to MidTRAM, field investigators assign the wetland a Qualitative Disturbance Rating from 1 (least disturbed) to 6 (most disturbed; Appendix A) based on best professional judgement.

Table 3. Metrics measured with the Delaware Rapid Assessment Procedure Version 6.0.

Attribute Group	***Metric Name***	***Description***	***Measured in AA or Buffer***
Habitat	Dominant Forest Age	Estimated age of forest cover class	AA
Habitat	Forest Harvesting within 50 Years	Presence and intensity of selective cutting or clear cutting within 50 years	AA
Habitat	Forest Management	Conversion to pine plantation or evidence of chemical defoliation	AA
Habitat	Vegetation Alteration	Mowing, farming, livestock grazing, or lands otherwise cleared and not recovering	AA
Habitat	Presence of Invasive Species	Presence and abundance of invasive plant cover	AA
Habitat	Excessive Herbivory	Evidence of herbivory or infestation by pine bark beetle, gypsy moth, deer, nutria, etc.	AA
Habitat	Increased Nutrients	Presence of dense algal mats or the abundance of plants indicative of increased nutrients	AA
Habitat	Roads	Non-elevated paths, elevated dirt or gravel roads, or paved roads	AA
Hydrology	Ditches (flats and depressions only)	Depth and abundance of ditches within and adjacent to the AA	AA and Buffer

Table 3, continued:

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*
Hydrology	Stream Alteration (riverines only)	Evidence of stream channelization or natural channel incision	AA
Hydrology	Weir/Dam/Roads	Man-made structures impeding the flow of water into our out of the wetland	AA and Buffer
Hydrology	Stormwater Inputs and Point Sources	Evidence of run-off from intensive land use, point source inputs, or sedimentation	AA and Buffer
Hydrology	Filling and/or Excavation	Man-made fill material or the excavation of material	AA
Hydrology	Microtopography Alterations	Alterations to the natural soil surface by forestry operations, tire ruts, and soil subsidence	AA
Buffer	Development	Commercial or residential development and infrastructure	Buffer
Buffer	Roads	Dirt, gravel, or paved roads	Buffer
Buffer	Landfill/Waste Disposal	Re-occurring municipal or private waste disposal	Buffer
Buffer	Channelized Streams or Ditches	Channelized streams or ditches >0.6 m deep	Buffer
Buffer	Poultry or Livestock Operation	Poultry or livestock rearing operations	Buffer
Buffer	Forest Harvesting in Past 15 Years	Evidence of selective or clear cutting within past 15 years	Buffer
Buffer	Golf Course	Presence of a golf course	Buffer
Buffer	Row Crops, Nursery Plants, Orchards	Agricultural land cover, excluding forestry plantations	Buffer
Buffer	Mowed Area	Any re-occurring activity that inhibits natural succession	Buffer
Buffer	Sand/Gravel Operation	Presence of sand or gravel extraction operations	Buffer

DERAP produces one overall wetland condition score based on the presence and intensity of various stressors. The final score obtained by DERAP is supported by the intensive DECAP Index of

Wetland Condition. The DERAP model was developed using a process to screen variables specific to each hydrogeomophic wetland class to select the most important variables that would represent wetland condition based on over 250 wetland sites (see Sifneos et al. 2010; Appendix B). Wetland stressors included in the DERAP model were selected using step-wise multiple regression and Akaike's Information Criteria (AIC) approach to develop the best model that correlated to DECAP data without over-fitting the model to this specific dataset. Therefore, certain wetland stressors are more important than other stressors, while some stressors are not included in final site scores. Coefficients, or stressor weights, associated with each stressor were assigned using multiple linear regression (Appendix C). The DERAP IWC score is calculated by summing the stressor coefficients for each of the selected stressors that were present and subtracting the sum from the linear regression intercept:

$$\textbf{DERAP IWC}_{\textbf{FLATS}} = 95 - (\sum \text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{RIVERINE}} = 91 - (\sum \text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{DEPRESSION}} = 82 - (\sum \text{stressor weights})$$

Example: Site D
Forested flat wetland with 25% of AA clear cut, 1-5% invasive plant cover, moderate ditching, and commercial development in the buffer:

DERAP condition score = 95 – (19+0+10+3)

DERAP condition score = 63

For all wetland subclasses, 23 items were selected to be included in the DERAP IWC calculation: 7 habitat stressors, 6 hydrology stressors, and 10 landscape or buffer stressors (Appendix C).

Comprehensive Sampling in Non-tidal Wetlands

We collected DECAP data from 1 riverine wetland and 1 flat wetland in the Mispillion watershed, from which DERAP was also collected. We followed the Delaware Comprehensive Assessment Procedure as outlined in the protocol (Jacobs et al. 2008). This data will be combined with other DECAP data from sites throughout Delaware to continue to validate and calibrate the DERAP. Data from the riverine can be found in Appendix H and data from the flat can be found in Appendix I. The wetland function scores and Index of wetland condition (IWC) can be found in Appendix J.

Presenting Wetland Condition

We present our results at both the site- and population-level. We discuss site-level results by summarizing the range of scores that we found in sampled sites (e.g. habitat attribute scores ranged from 68 to 98). Population level results are presented using weighted means and standard deviations (e.g. habitat for tidal wetlands averaged 87 ± 13) or weighted percentages (e.g. 20% of riverine wetlands had channelization present). Population level results have incorporated weights based on the probabilistic design and correct for any bias due to sample sites that could not be sampled and different rates of access on private and public lands to be able to extrapolate to the total area of wetland in the watershed. The cumulative results represent the total area of the respective wetland subclass for the entire watershed.

Sites in each HGM subclass were placed into 3 condition categories: Minimally stressed, Moderately stressed, or Severely stressed (Table 4). Condition class breakpoints were determined by applying a percentile calculation to the QDR's and condition scores from sites in several previously assessed watersheds. Non-tidal regional datasets includes DERAP data from St. Jones, Murderkill, Inland Bays, and Nanticoke watersheds (n = 160). Minimally stressed sites are those with a condition score greater than the 25th percentile of sites assigned a QDR of 1 or 2. Severely stressed sites are those with a condition score less than the 75th percentile of sites assigned a QDR of 5 or 6. Moderately stressed sites are those that fall between. The condition breakpoints that we applied in the Mispillion River watershed are provided in Table 4.

Table 4. Condition categories and breakpoint values for tidal and non-tidal wetlands in the Mispillion River watershed as determined by wetland condition scores.

Wetland Type	Method	Minimally or Not Stressed	Moderately Stressed	Severely Stressed
Estuarine	MidTRAM	≥ 81	< 81 ≥ 63	< 63
Riverine	DERAP	≥ 85	< 85 ≥ 47	< 47
Flats	DERAP	≥ 88	< 88 ≥ 65	< 65
Depression	DERAP	≥ 73	< 73 ≥ 53	< 53

We used a cumulative distribution function (CDF) to display wetland condition on the population level. A CDF is a visual tool that extrapolates assessment results to the entire watershed population and can be interpreted by drawing a horizontal line anywhere on the graph and reading that as: 'z' proportion of the area of 'x wetland type' in the watershed falls above (or below) the score of 'w' for wetland condition. The advantage of these types of graphs is that they can be interpreted based on individual user goals, and points can be placed anywhere on the graph to determine the percent of the population that is within the selected conditions. For example, in Figure 9 roughly 40% of the wetland area scored above an 80 for wetland condition. A CDF also highlights cliffs or plateaus where either a large or small portion of wetlands are in similar condition. In the example, there is a condition plateau from 50 to approximately 75, illustrating that only a small portion of the population had condition scores in this range.

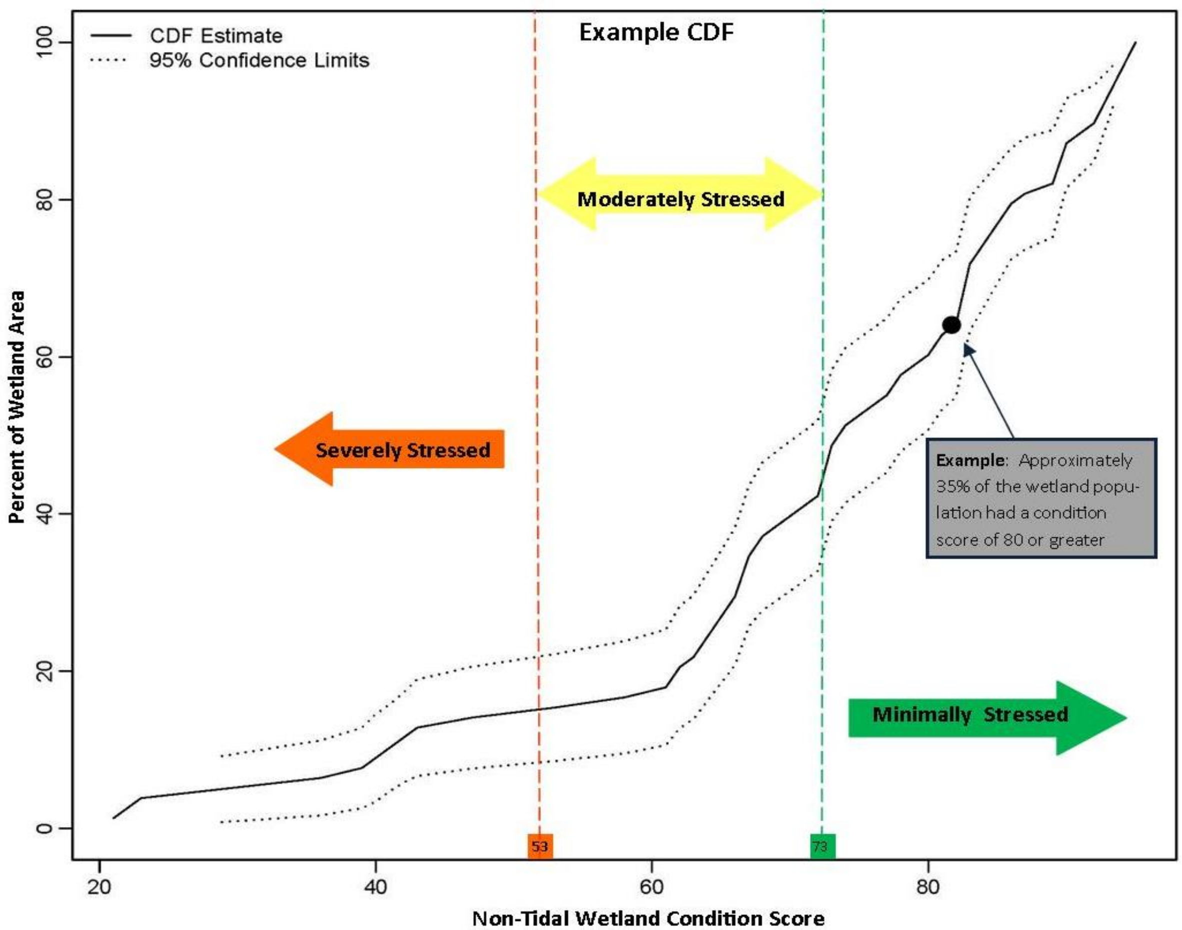
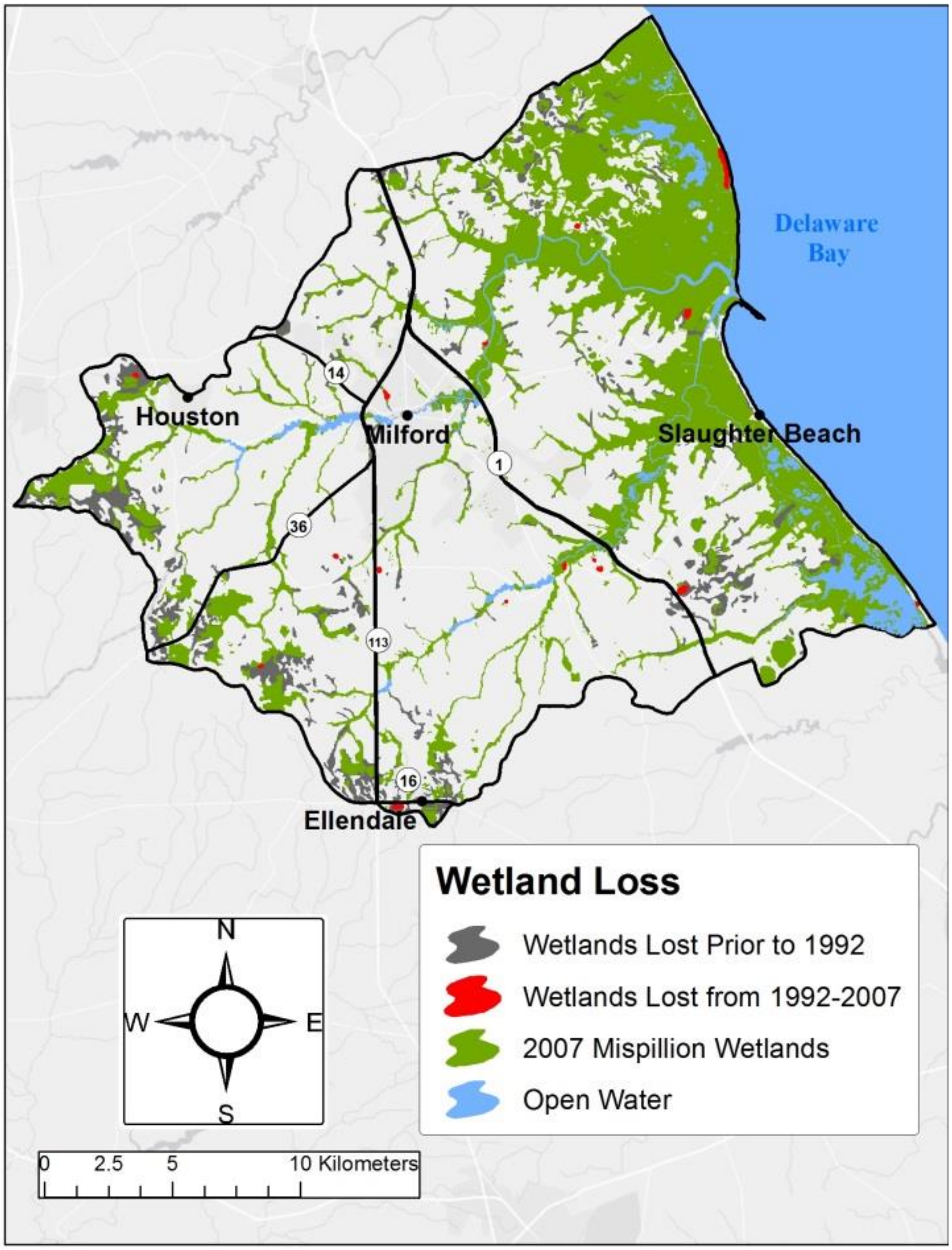


Figure 9. An example CDF showing wetland condition. The black line is the population estimate and the dashed gray line is the 95% confidence intervals. The orange and green dashed lines show the breakpoints between condition categories.

RESULTS

Landscape Analysis of Changes in Wetland Acreage

Wetlands historically covered nearly 23,000 acres across the Mispillion watershed. A comparison of estimated historic wetlands to 2007 wetlands indicated that 19% of wetland acreage has been lost due to conversion to other land uses between the time of settlement and 2007. Historic wetland losses occurred throughout the watershed but the majority of losses came from flats being converted to agriculture. Some riverine wetlands along the Mispillion River and Cedar Creek were also converted to agriculture.



Map 5. Estimates historic and more current wetland coverage in the Mispillion River Watershed

A comparison of wetland maps from 1992 and 2007 indicated that 38 acres of wetlands were lost to conversion; 19 acres of flats, 13 acres of estuarine, almost 5 acres of depressions and 1 acre of riverine wetlands (Map 5). Statewide trends reported that freshwater forested wetlands sustained the greatest losses over this time period and the Mispillion watershed correlates with that.

Between 1992 and 2007 the maps reported a gross gain of 76 acres which equaled a net gain of 41 acres. The increase in wetland acreage was largely due to creation of stormwater retention or agricultural ponds (62%) and the other 38% was successional habitat or marsh migration into agricultural fields. The increase in stormwater ponds is chiefly related to the increase in development in the watershed and the creation of required stormwater ponds. Also, refined mapping methods and analysis are increasingly able to detect and record wetlands on a finer scale. Created stormwater ponds serve a water holding capacity and as wildlife habitat to some extent but do not perform wetland functions on par with natural wetlands. Although the Mispillion watershed gained wetland acreage, the statewide wetland trends report reported an overall loss of wetland acreage and confirmed the increase in wetlands were mostly low functioning stormwater ponds (Tiner et al. 2011).

As a result of recent changes in wetland acreage, the wetland functions being performed in the Mispillion watershed have been impacted. A recent landscape-level analysis of wetland function predicted that, as a result of wetland losses between 1992 and 2007, the potential for existing wetlands to perform nutrient transformation, sediment retention, surface water detention, and serve as wildlife habitat were reduced (Tiner 2011). The replacement of natural wetlands with stormwater retention ponds can also negatively affect wildlife that use these habitats for breeding, nesting, or foraging. In developed landscapes, unnatural hydroperiods and the accumulation of contaminants in stormwater ponds can create ecological traps for birds, reptiles, and amphibians (Brand et al. 2010).

Tidal wetlands are regulated through the State of Delaware's wetland permitting program in combination with federal regulations which prohibits losses. Aside from the previously mentioned losses the Mispillion watershed also experienced a change of 28 acres of estuarine wetlands between 1992 and 2007 from estuarine fringe wetlands to estuary flooded areas. All of these wetlands were located behind the Delaware Bay beach and dunes where the beach has now eroded back into the wetlands (Map 5). The shoreline has migrated into the wetlands and turned estuarine wetlands into sandy dunes or shallow benthic habitat which is now part of the Delaware Bay. In some locations the shoreline has migrated over 20 meters from its location in 1992. This exemplifies the threat that these habitats are facing, from rising sea levels to conversion and development. The conversion of coastal wetlands to open water is a topic of great concern being addressed as DNREC plans for adapting to sea level rise and climate change (State of Delaware 2012).

Landowner Contact and Site Access

We obtained landowner permission prior to accessing and sampling any sites. Landowners were identified using county tax records and were mailed a post card providing them with some basic information on our study goals, sampling techniques, and contact information. They were encouraged to contact us with any questions or concerns regarding access, data collection and reporting. The majority of our sampled sites (61%) were privately owned leaving the remaining portion under public ownership such as state, federal or conservation partners (Figure 10).

In order to complete 34 tidal wetland condition assessments we considered a total of 46 tidal sites. Of the 12 sites we did not access, we did not receive permission from 7 sites, 4 sites did not have the adequate habitat to sample, and one site was inaccessible (Figure 10). Of the 34 tidal sites we sampled, 18 (53%) were on public property and 16 (47%) were publicly owned. We sampled 45 of the 76 flat sites

(59%) that we attempted. Of the 31 sites not sampled, 18 were not adequate habitat, 11 sites we did not receive permission to access, 1 site we could not contact the owner, and 1 site was inaccessible. Of the 45 flats that were sampled, 27 sites (60%) were located on private property and 40% were publicly owned.

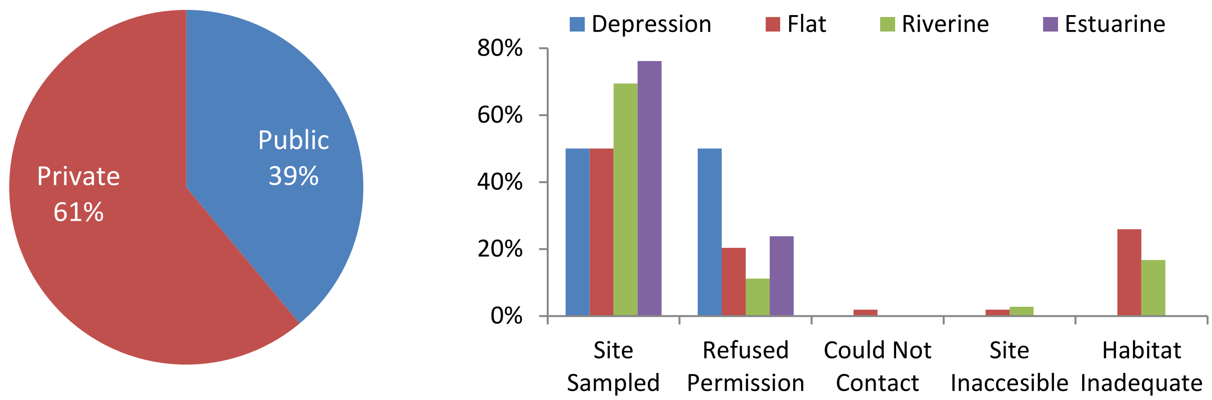
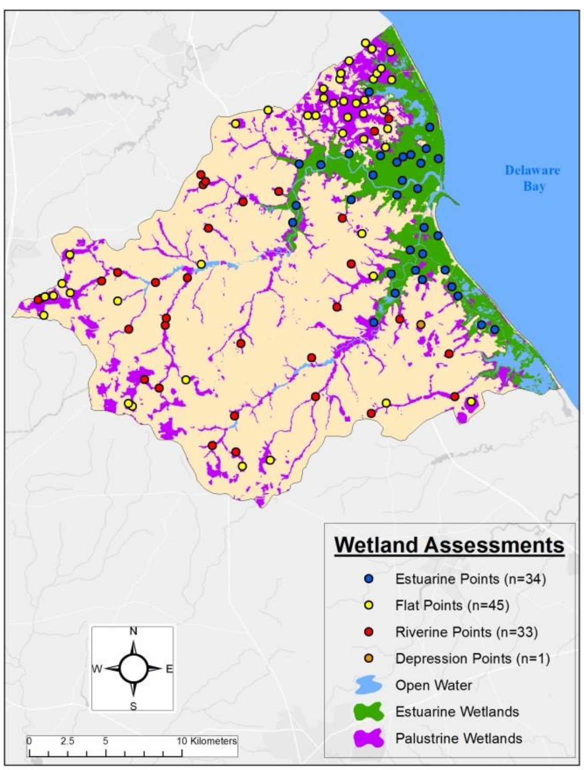


Figure 10. Ownership of sampled wetland sites in the Mispillion River Watershed (*left*) and success rates for sampling private wetland sites (*right*).

We evaluated 45 riverine sites in the process of reaching our sample of 33. We did not receive permission for 4 sites, one of the sites was inaccessible, and 7 sites were inadequate habitat. Of the 33 riverine sites we sampled, 25 (76%) were on private property leaving just 8 (32%) on public land. Depression wetlands represented a small portion of wetlands in the Mispillion watershed. Two sites were identified on private lands; we sampled 1 site and did not get permission to access the other site (Figure 10). We sampled a total of 113 sites located throughout the watershed (Map 6).



Map 6. Location of wetland assessments performed in the Mispillion River watershed in 2012.

Wetland Condition

Tidal Wetland Condition

Tidal estuarine wetlands comprised 49% (10,704 ac) of the total wetland acreage in the Mispillion watershed and provided valuable ecosystem services to the communities that reside in these coastal areas. Tidal wetlands are responsible for absorbing storm surges and protecting communities from damaging wave energy, controlling coastal erosion, trapping loose sediments and harmful pollutants out of the water column, and producing populations of fish and shellfish. Tidal wetlands are a diverse and productive ecosystem with many fish, birds, and aquatic species using these marshes at some point in their lives from reproduction to seasonal migration stopovers. The tidal estuarine wetlands in the Mispillion watershed were fringing or expansive salt marshes with salinities ranging 5-30ppt.

Tidal wetlands in the Mispillion Watershed were in fair condition with an average score of 74.3±7, ranging from 48 to 84. The top 3% of tidal population scored >83 and were characterized as having intact hydrology, and wide buffers with minimal disturbance. The bottom 7% of the tidal wetland population scored <60 and were all impacted by barriers to landward migration, development in the buffer, and a strong presence of invasive species. Appendix D provides the raw values and scored metrics for the 34 tidal sites.

The Buffer attribute group was the strongest component for tidal wetlands with an average score of 84.5±15, ranging widely from 26 to 100 (Figure 11). The majority of tidal wetlands in this watershed are generously buffered by natural habitat free from development and shoreline structures. In a landscape where the marsh to upland border is not hardened by manmade features such as roads or bulkhead wetlands can migrate inland in response to rising water levels, allowing them to persist under changing conditions. In the Mispillion watershed tidal wetlands over 91% of the wetlands have an unobstructed migration route into upland habitat. The small proportion of tidal wetlands scoring poorly for buffer was impacted by the presence of Phragmites, human dwellings and an upland dominated by row crop farming which causes soil disturbance and intense human visitation.

In the Hydrology attribute group tidal wetlands earned an average score of 79.9±10, ranging moderately from 58 to 100 (Figure 11). Seventy percent of tidal wetlands have altered hydrology due to grid ditching which is often paired with impacts due to the resulting spoils piles which are considered fill. Mosquito ditches built in the 1930's are still intact and functioning and spoil piles are still evident, marked by vegetation such as *Iva* taking advantage of the small islands of higher elevation. The structured channel and opening at the convergence of the Mispillion River and the Delaware Bay was determined to be a source of tidal restriction, thus every tidal wetland was considered to have slightly impacted hydrology as a result. Point source pollution was not an issue for this wetland type as none of the tidal wetlands evaluated had culverts, pipes, or ditches found inside the wetland.

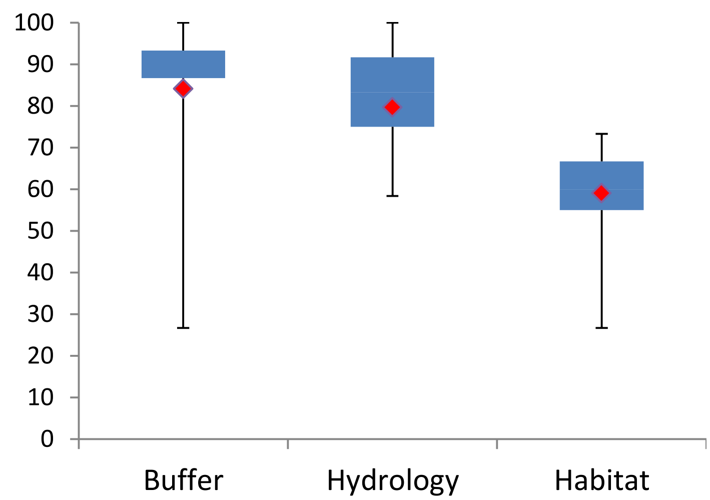
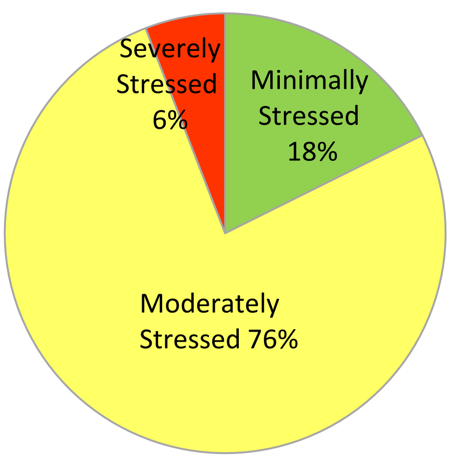


Figure 11. Attribute group score range, mean and standard error for (L to R) Buffer, Hydrology, and Habitat categories from tidal wetlands in the Mispillion River watershed.

Habitat was the poorest scoring component for tidal wetlands, yielding an average of 58.4± 12, with scores ranging from 26 to 73 (Figure 11). The condition scores captured somewhat limited plant diversity and less than robust vegetation thickness. Plant community scores were also diminished by the presence of *Phragmites*. In most cases native plants were firmly intact but in a small portion (15%) of tidal wetlands invasive species dominated (>50%) the plant community.

Tidal wetlands of the Mispillion watershed had an organic layer of at least 13cm for all sites with the majority of sites with a depth of more than 16cm. The wetlands had a thick organic layer and this was further strengthened by the average bearing capacity of 3.85 cm. The bearing capacity is associated with marsh stability and below ground biomass, the lower the number the more stable the marsh platform is. A loss of below ground organic matter may precede the above ground loss of organic matter, which could be determined by taking bearing capacity readings of a wetland. Invasive plants were found throughout the watersheds wetlands with 47% of tidal wetlands containing invasive species. Common Reed (*Phragmites australis*) was the most common invasive in the watershed but some of the wetlands also had Narrowleaf cattail (*Typha angustifolia*) present.

Overall, when compared to other tidal wetlands in Delaware and divided in condition categories, 18% of tidal wetlands in the Mispillion watershed were minimally or not stressed and therefore in good condition (Figure 12 *left*). The majority of tidal wetlands (76%) were moderately stressed and 6% of tidal wetlands were severely stressed (Figure 12 *left*). Condition assessment results indicate that 82% of tidal wetlands in the Mispillion watershed are impacted by stressors and are functioning at a reduced capacity as a result. In a side-by-side comparison of condition categories, there is an incremental increase in the proportion of tidal wetlands impacted by invasive plants, ditching and fill with decreasing condition (Figure 12 *right*).



Metric	Minimally Stressed *n*=6	Moderately Stressed *n*=26	Severely Stressed *n*=2
Invasive Species Present	<1%	13%	73%
Wetlands with Fill	0%	23%	50%
Buffer Width (max=250m)	229	223	124
Wetlands with Ditching	50%	73%	100%

Figure 12. Proportion of tidal wetlands by condition category for the Mispillion River watershed (left) and the occurrence of common wetland stressors (right) of tidal wetlands in the Mispillion River Watershed.

The cumulative distribution function takes the sample population and extrapolates the condition results to the watershed level. The cumulative distribution function graph for tidal wetlands in the Mispillion watershed shows that tidal wetlands are skewed towards a higher condition, with almost 75% of the wetlands scoring above a 70 (Figure 13). The majority of tidal were found to be moderately stressed.

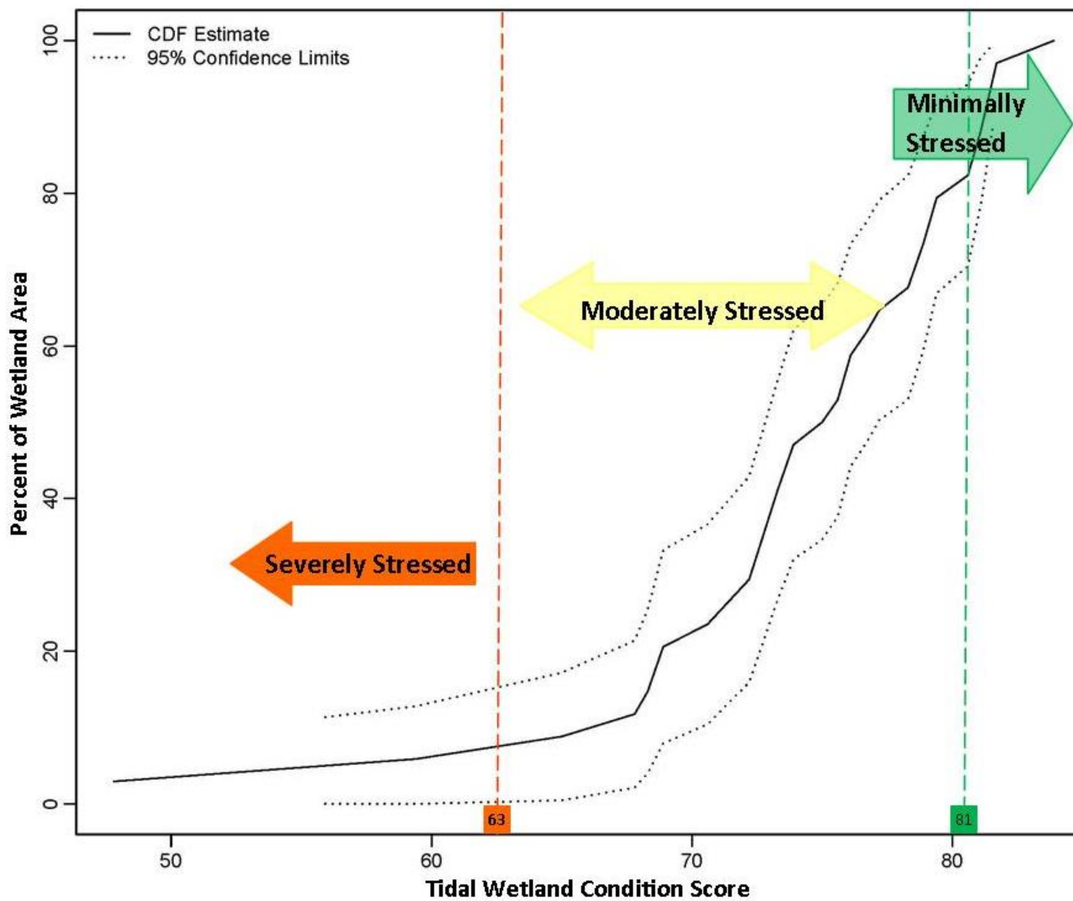


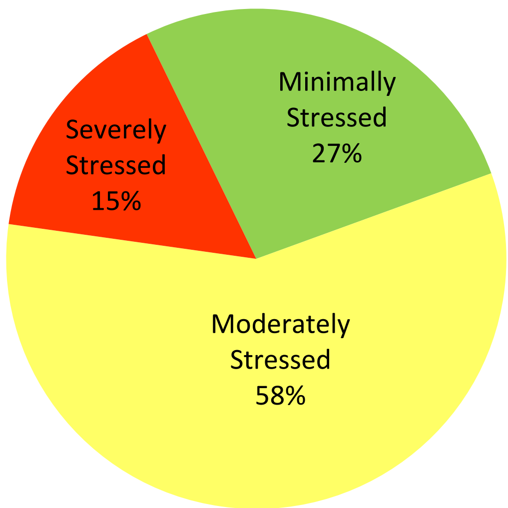
Figure 13. Cumulative distribution function for tidal wetlands in the Mispillion watershed. The orange and green vertical dashed lines signify the condition category breakpoints dividing severely stressed from moderately and minimally stressed portions of the tidal wetland population.

Headwater Flat Wetland Condition

Forested headwater flat wetlands made up 30% (6,493 ac) of the wetland population in the Mispillion River watershed, occurring in low-lying, forested headwater areas. The majority of flat wetlands in Mispillion watershed were found in the northeastern and western portions. Flat wetlands are valued for their ability to filter pollutants such as chemicals and excess nutrients coming off surrounding lands before reaching streams and rivers, thus improving water quality. Flat wetlands also provide ample habitat to wildlife.

Wetland condition scores for flats averaged 76.5$\pm$14 and ranged from 53-95. Nearly three quarters (73%) of flat wetlands were moderately or severely stressed, leaving only about a quarter (27%) not or minimally stressed by wetland impacts and stressors (Figure 14 *left*). Invasive plants such as honeysuckle (*Lonicera japonica*) were found throughout this wetland class with the occurrence increasing with decreasing condition (Figure 14 *right*). Of the sampled flats that contained invasive plants (55%) only a small portion had invasive species dominating (>50%) the vegetation community. Forestry activity in the form of selective cutting represented a common habitat alteration affecting more than one third

(38%) of headwater flats in the Mispillion watershed. Fill or excavation within the wetland boundary was a common source of hydrology impacts, occurring at most sites. One third of all flat wetlands had a road located in the 100m buffer surrounding the 40m assessment area (Figure 14 *right*).



Metric	Minimally Stressed *n*=12	Moderately Stressed *n*=26	Severely Stressed *n*=7
Invasive Species Present	25%	62%	71%
Forestry Activity	25%	38%	43%
Roads in Buffer	0%	38%	57%
Fill in Wetlands	8%	73%	86%
# of Buffer Stressors	<1	1.7	2

Figure 14. Composition of wetland condition classes (left) and the occurrence of common wetland stressors (right) of headwater flat wetlands in the Mispillion River Watershed.

The most commonly detected habitat stressors in flat wetlands were forestry activities and the presence of invasive species, and the most common hydrology stressors were ditching and filling or excavating within wetlands. Nearby agricultural activity and roads were the most common buffer stressors found. The rapid assessment stressor dataset from 45 flat sites in the Mispillion watershed are provided in Appendix E.

The cumulative distribution function of the Mispillion watershed flats population is skewed toward the higher condition, with 75% of flat wetlands scoring 70 or better. Approximately 27% (1,750 ac) of flats in the Mispillion watershed were estimated to be minimally stressed; generally these wetlands have wide buffers, low occurrence of invasive plant species, and intact hydrology. While the bottom 10% of wetlands scored below 60, and are characterized by having extensive invasive plant species present, altered hydrology, and have multiple stressors in the surrounding landscape.

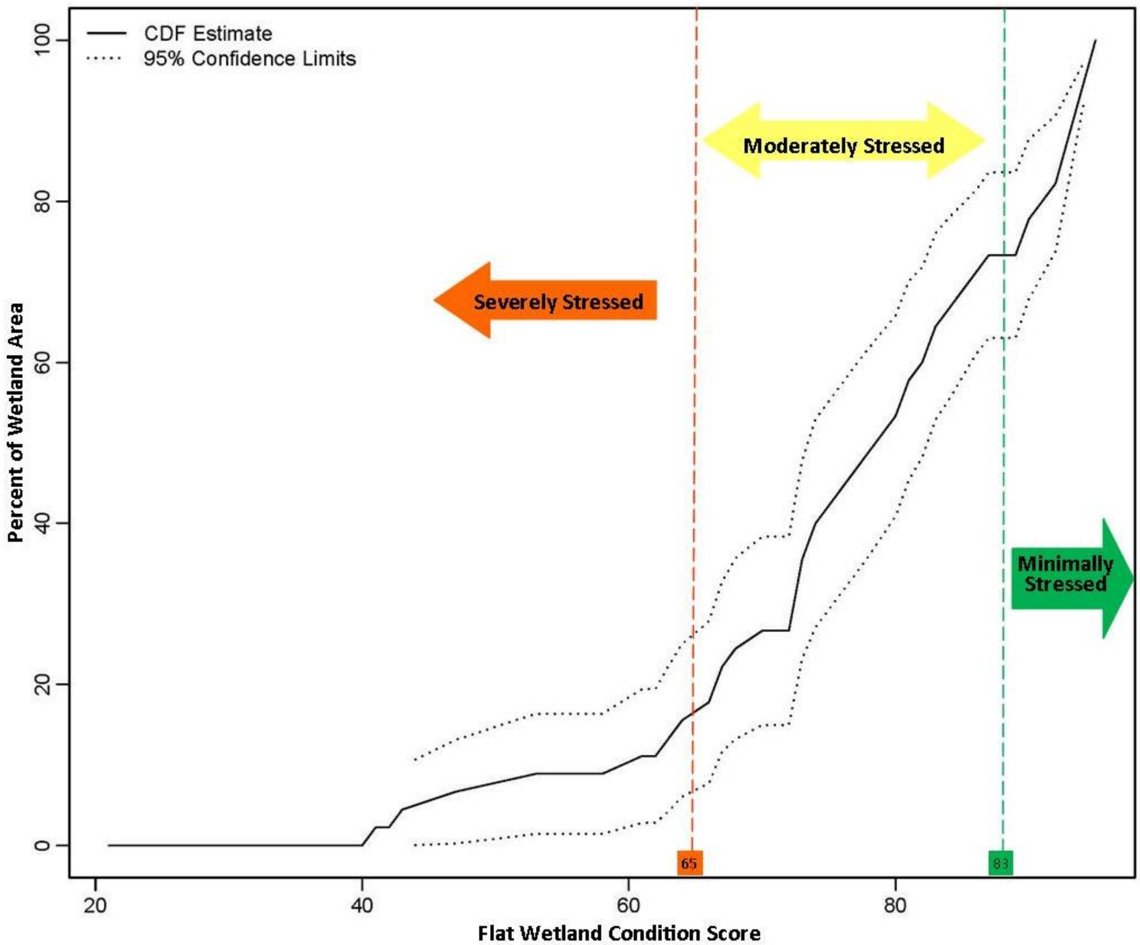
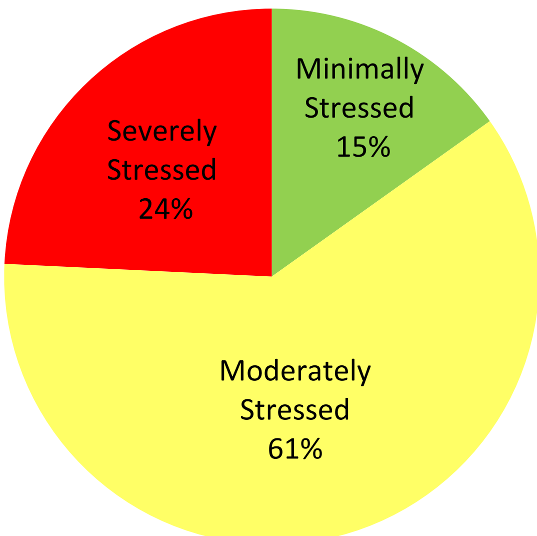


Figure 15. The cumulative distribution function for flat wetlands in the Mispillion watershed. Condition scores for the wetland population are represented as the black line. The orange and green vertical lines designate condition category breakpoints dividing severely stressed, moderately stressed, and minimally stressed wetlands.

Riverine Wetland Condition

Riverine wetlands are associated with the floodplains of the Mispillion River and Cedar Creek, and its tributaries. Riverine wetlands comprise 15% of the watershed's wetlands, which amounts to approximately 3,156 acres (1,277 hectares). Riverine wetlands are an important habitat type because they act as a buffer between surface flowing waterways and surrounding uplands and provide water storage when these streams and rivers overflow their banks. Riverine wetlands are also valued for serving as vital corridor habitat for plants and wildlife, connecting large natural areas that may otherwise be isolated among developed or un-natural land.

The maximum score possible for a riverine wetland using DERAP is a 91. Riverine wetlands in the Mispillion watershed scored widely from 21 to 90 and averaged 64±21. The majority (61%) of the riverine wetlands were moderately stressed, 15% minimally or not stressed, and 24% severely stressed (Figure 16 *left*). Invasive plants such as honey suckle and multiflora rose were a widespread problem detected at 76% of riverine wetlands in the watershed. Additional habitat stressors included forestry activity such as selective harvest or clear cutting (39%). Stream alteration is a riverine-wetland specific stressor that is used to note when a natural waterway has been dug out and channelized, perhaps straightened, often leaving a spoil pile along one or both banks which interrupts storm water from overflowing during or after rain events, thus disconnecting the waterway from adjacent wetlands. Impacts to hydrology including stream alteration, or structures such as roads or dams occurred in 28% of riverine wetlands. Filling or excavating in a wetland can disrupt the natural hydrology of a site, which can alter the plant community. Forty-two percent of riverine wetlands the Mispillion watershed had some form of filling or excavating. A disturbed plant community, stream alterations, development in the buffer and fill/excavation were increasingly common with decreasing condition (Figure 16 *right*).



Metric	Minimally Stressed *n*=5	Moderately Stressed *n*=20	Severely Stressed *n*=8
Invasive Species Present	40%	75%	100%
Stream Alteration	0%	11%	88%
Development in Buffer	0%	50%	63%
Fill in Wetland	0%	35%	88%

Figure 16. Composition of wetland condition classes (left) and the occurrence of common wetland stressors (right) for riverine wetlands in the Mispillion River watershed.

Development in a wetland eliminates the wetland and its ability to function. Development or agriculture adjacent to a wetland can cause indirect impacts such as polluted runoff from roads, lawns or fields, as well as the introduction of invasive plants, and altered upstream hydrology. Eighty-two percent of riverine wetlands had either development, agriculture, and/or roads in the surrounding buffer habitat. If wetlands are healthy and properly functioning, riparian wetlands have the potential to serve a great function to draw in pollutants and protect against flooding. Thus it is important to allow wetlands to maintain healthy plant communities and hydrology so we can benefit from their natural services.

The cumulative distribution function shows a large portion of riverine wetlands in the moderately stressed category (Figure 17). A plateau from 42 to about 60 indicates that a very small portion of riverine wetlands fell into this condition range. This gap reveals a challenge for improving impacted riverine wetlands through restoration; there is an opportunity to improve wetlands in poor condition and even out the distribution across the watershed. Inversely, a sharp rise around 82 indicates that about 10%

of riverine wetlands are very close to the highest condition category threshold. With a little bit of restoration the health of the population could improve greatly. The rapid assessment stressor dataset from 33 riverine sites in the Mispillion watershed are provided in Appendix F.

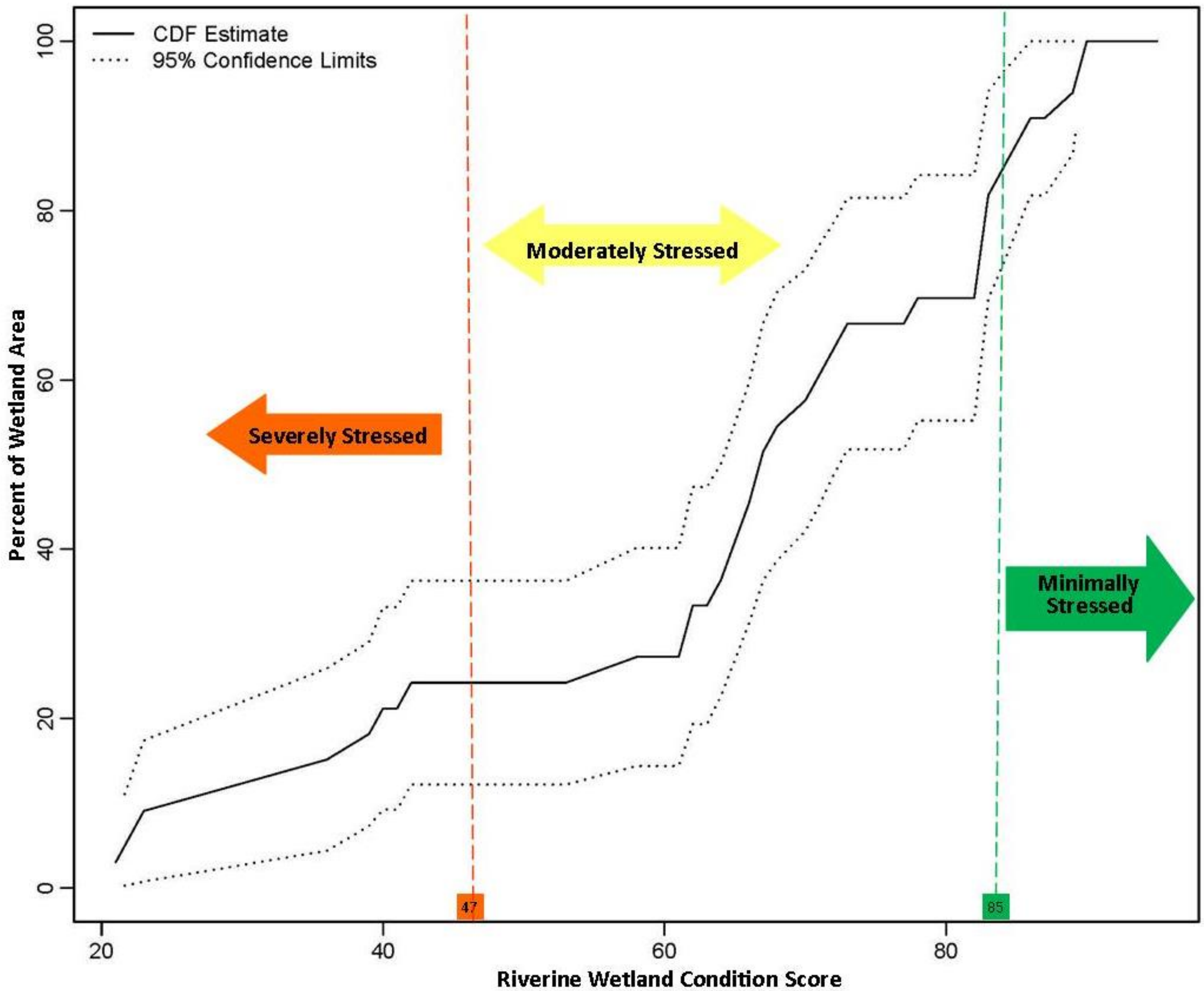


Figure 17. Cumulative distribution functions for non-tidal riverine wetlands in the Mispillion River watershed. Condition scores for the wetland population are represented as the black line. The orange and green dashed lines designate condition category breakpoints dividing severely stressed, moderately stressed, and minimally stressed wetlands.

Depression Wetland Condition

Depression wetlands were found throughout the watershed, comprising 563 hectares (1,390 acres) which is approximately 6% of the wetland population in the Mispillion watershed. Depression wetlands are located in low-lying areas, where they are fed by groundwater, rainfall, and snowmelt. Depression wetlands are often dry on the surface in the summer and fall. Although the proportion of depression wetlands in the watershed was small, they included some rare habitats, such as Delmarva bays or Coastal

Plain Ponds. These rare wetland types provide vital habitat to many of the state's rare and threatened plants and animals, including tiger salamanders *(Ambystoma tigrinum)* and barking treefrogs *(Hyla gratiosa).* While depression wetlands are home to some of the state's rarest species, they also store storm water, collect nutrients, and improve water quality by retaining sediment and filtering storm water. Due to their rare occurrence on the landscape, they were not often selected in the random site drop; thus only 1 depression site was assessed as part of this study. Due to the limited sample size, no conclusions could be accurately drawn on the condition of the depression wetland subclass. The DERAP stressor checklist from the depression assessment can be found in Appendix G.

Overall Condition and Watershed Comparison

For an overall view of wetland condition in the Mispillion watershed compared to five other previously assessed watersheds, we combined the condition proportions for the major wetland types (tidal, flat, riverine, and depression) based on the acreage of each type in the watershed (Figure 18).

Moderately stressed wetlands dominated the Mispillion watershed with 64% of the total wetlands. The Mispillion watershed has a very similair breakdown of wetland health as the Broadkill watershed, which is located just south and adjacent to the Mispillion watershed. The Mispillion watershed had the 2nd highest percent of moderately stressed wetlands of the 6 watersheds completed so far. Mispillion also had the third highest severely stressed wetlands and the fourth highest minimally stressed wetlands out of six watersheds (Figure 18).

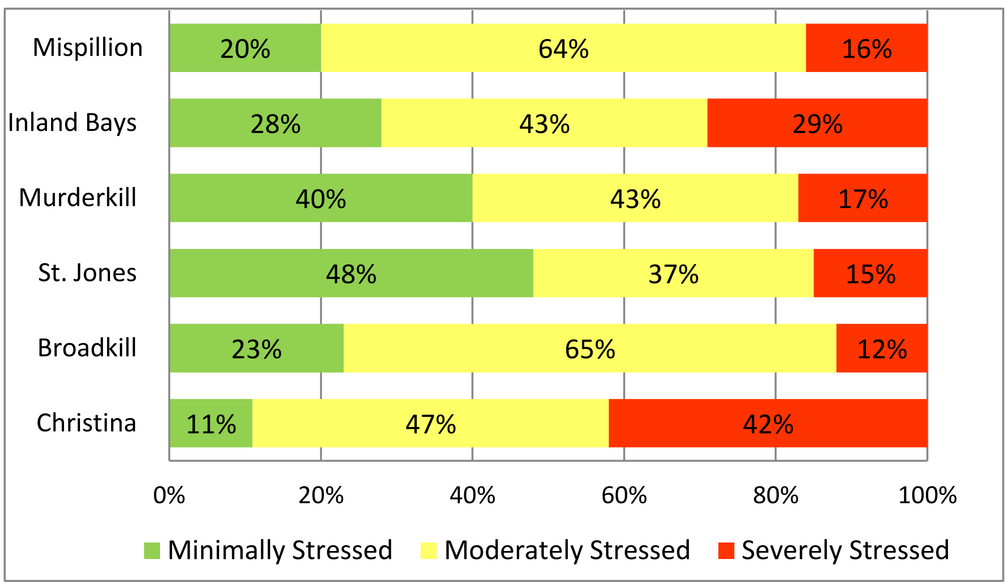


Figure 18. Combined condition proportions for tidal, flat, riverine, and depression wetlands in the Mispillion River watershed, compared to wetland conditions in the St. Jones, Muderkill, Inland Bays, Christina, and Broadkill watersheds.

MANAGEMENT RECOMMENDATIONS

The results of this study identify how and where wetland acreage is changing in the watershed, what condition wetlands are in and what stressors are impacting their health and ability to function. Based on the findings of this study we propose eight management recommendations to improve the condition and extent of wetlands in the Mispillion watershed:

1. **Preserve remaining ecologically significant wetlands.** Coastal plain seasonal ponds, also known as Delmarva Bays, and Atlantic white cedar wetlands have been identified as regionally-unique wetland types and are considered irreplaceable and a significant component of Delaware's natural heritage (McAvoy and Clancy 1994). These wetlands contain unique hydrological and biological characteristics that are imperative for the survival of many plants and animals in Delaware. Many Delmarva bays and Atlantic white cedar wetlands throughout the state have traditionally been drained or filled and are exceedingly rare in Delaware. The Mispillion River watershed contains an estimated 188 acres of Delmarva bays and 487 acres of Atlantic white cedar wetlands. Protecting Delmarva bays and Atlantic white cedar wetlands from impacts and conversion with biologically-significant buffers through easements and planning will preserve these irreplaceable wetlands. Unavoidable impacts should be mitigated with a high ratio of compensation of at least 3:1.

2. **Support Delaware's Bayshore Initiative by securing funding for wetland restoration and preservation**. As part of President Obama's America's Great Outdoors initiative, the Delaware Bayshore Initiative was created to preserve Delaware's coastal heritage and increase recreation utilizing landscape-scale conservation practices. Approximately 100 square miles of the Mispillion River watershed is within the targeted Bayshore region, including most of the watershed's tidal marshes and most of the watershed's depression wetlands. The most proactive approach to conserving wetland resources is to protect wetlands in high condition that have not been impacted by stressors. The Delaware Bayshore Initiative will pool conservation resources to efficiently improve coastal habitat access and preservation.

3. **Control the extent and spread of the non-native, invasive common reed (*Phragmites australis)***. Invasive plants such as *Phragmites* are capable of spreading rapidly, outcompeting native species, reducing plant diversity in undisturbed areas, and reducing the success of other organisms by changing habitat structure and food availability. The DNREC Phragmites Control Program in the Division of Fish and Wildlife has treated more than 20,000 acres on private and public property since 1986. Without continued support from state funds and federal State Wildlife Grant funds *Phragmites* will degrade more wetlands. If *Phragmites* was eradicated from tidal wetlands, the average habitat scores would increase 9% from 58% to 67% and only 3% of the tidal wetlands in the Mispillion River watershed would be severely stressed (a 50% reduction).

4. **Improve protection of nontidal wetlands**. Activities in nontidal wetlands are not regulated by the State of Delaware. Every additional wetland filled or destroyed contributes to a reduction of water quality, wildlife habitat, and flood abatement services, and increases societal costs for providing man-made alternatives to these services. Improved protection for nontidal wetlands is needed to fill the gaps left by recent Supreme Court decisions and to provide a comprehensive and clear means to protect wetlands across the state. A state regulatory program in concert with county and local programs would reduce the ambiguity surrounding which wetlands are regulated and provide a comprehensive and clear means to protect wetlands in the entire state. Local regulations can be incorporated into municipal and/or county code and home owner associations to protect wetland areas of special significance. Also, consider protecting high quality wetlands using fee simple acquisitions and conservation easements. We can encourage better protection at the state and local level by educating the public and decision makers on the importance of wetlands within the watershed.

5. **Update tidal wetland regulatory maps**. In addition to improving the protection of nontidal wetlands, it is prudent to maximize the authority that already exists within DNREC. Tidal wetland impacts are regulated by the State of Delaware within DNREC and permit reviewers need accurate and recent wetland maps to guide wetland permitting. Likewise, landowners and designers would benefit by using accurate maps for planning and designs. Currently maps from 1988 are used as the state regulated tidal wetland maps, which must be verified in person due to incongruities and are difficult to read. Evidence of recent coastal development and inundation of coastal wetlands due to sea level rise creates a greater need to adopt updated wetland maps as regulatory maps.

6. **Design a wetland restoration plan for the lower Delaware Bay Basin that includes the Mispillion River watershed**. This involves a science-based process that uses existing data to identify restoration and protection priority properties pertinent to forestry, agriculture, wetlands, restoration, soils, wildlife and botany branches of state, federal and non-profit organizations. The plan would lead to the implementation of restoration and conservation opportunities on private and public property across the Delaware Bay Basin and Mispillion River watershed. A partial basin-wide plan will combine resources, time, and manpower to plan for multiple watersheds. Roughly 13,825 acres of wetlands in the Mispillion were moderately stressed which identified a need for restoration before impacts reduce them to severely stressed. Severely stressed wetlands are likely more difficult and costly to restore.

7. **Improve the protection of flats**. Headwater flats incurred the most acreage loss recently through land use conversion which makes protecting those remaining more important. This study found that just over a quarter of remaining flats were in healthy condition and the priority is to prevent impacts from reducing their functional capacity. Protecting the top condition portion of the population will capitalize on their role in the watershed for improving water quality, providing

important habitat and storing flood waters. Also, to ensure that flats in moderate condition, which were mostly impacted by forestry activities, are being harvested using sustainable practices under a certified Forest Management Plan to allow them to regenerate to native forest communities with healthy hydrology.

8. **Develop incentives to maintain natural buffers of tidal wetlands**. As sea levels rise and extreme storm events bring more flooding, the importance of wetland buffers between water and upland is taking center stage. The need exists to inform Delawareans on the importance of allowing tidal wetlands to migrate inland unobstructed by roads, rip-rap and bulkheads. Barriers to landward migration do not allow marshes to keep pace with sea level rise and when these habitats are converted to open water it prevents them from buffering coastal storms. The low occurrence of hardened shorelines in Mispillion River watershed is uncommon in Delaware and should be preserved. In addition to awareness, an incentive program could attract an interest in maintaining natural buffers between wetlands and development.

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APPENDIX A: Qualitative Disturbance Rating (QDR) Category Descriptions

Qualitative Disturbance Rating: Assessors determine the level of disturbance in a wetland through observation of stressors and alterations to the vegetation, soils, hydrology in the wetland site, and the land use surrounding the site. Assessors should use best professional judgment (BPJ) to assign the site a numerical Qualitative Disturbance Rating (QDR) from least disturbed (1) to highly disturbed (6) based on the narrative criteria below. General description of the minimal disturbance, moderate disturbance and high disturbance categories are provided below.

Minimal Disturbance Category (QDR 1 or 2): Natural structure and biotic community maintained with only minimal alterations. Minimal disturbance sites have a characteristic native vegetative community unmodified water flow into and out of the site, undisturbed microtopographic relief, and are located in a landscape of natural vegetation (100 or 250 m buffer). Examples of minimal alterations include a small ditch that is not conveying water, low occurrence of invasive species, individual tree harvesting, and small areas of altered habitat in the surrounding landscape, which does not include hardened surfaces along the wetland/upland interface. Use BPJ to assign a QDR of 1 or 2.

Moderate Disturbance Category (QDR 3 or 4): Moderate changes in structure and/or the biotic community. Moderate disturbance sites maintain some components of minimal disturbance sites such as unaltered hydrology, undisturbed soils and microtopography, intact landscape, or characteristic native biotic community despite some structural or biotic alterations. Alterations in moderate disturbance sites may include one or two of the following: a large ditch or a dam either increasing or decreasing flooding, mowing, grazing, moderate stream channelization, moderate presence of invasive plants, forest harvesting, high impact land uses in the buffer, and hardened surfaces along the wetland/upland interface for less than half of the site. Use BPJ to assign a QDR of 3 or 4.

High Disturbance Category (QDR 5 or 6): Severe changes in structure and/or the biotic community. High disturbance sites have severely disturbed vegetative community, hydrology and/or soils as a result of ≥1 severe alterations or >2 moderate alterations. These disturbances lead to a decline in the wetland's ability to effectively function in the landscape. Examples of severe alterations include extensive ditching or stream channelization, recent clear cutting or conversion to an invasive vegetative community, hardened surfaces along the wetland/upland interfaces for most of the site, and roads, excessive fill, excavation or farming in the wetland. Use PBJ to assign a QDR of 5 or 6.

APPENDIX B: DERAP Stressor Codes and Definitions

Habitat Category (within 40m radius of sample point)	
Hfor50	Forest age 31-50 years
Hfor30	Forest age 16-30 years
Hfor15	Forest age 3-15 years
Hfor2	Forest age ≤2 years
Hcc10	<10% of AA clear cut within 50 years
Hcc50	11-50% of AA clear cut within 50 years
Hcc100	>50% of AA clear cut within 50 years
Hforsc	Selective cutting forestry
Hpine	Forest managed or converted to pine
Hchem	Forest chemical defoliation
Hmow	Mowing in AA
Hfarm	Farming activity in AA
Hgraz	Grazing in AA
Hnorecov	Cleared land not recovering
Hinv1	Invasive plants cover <1% of AA
Hinv5	Invasive plants cover 1-5% of AA
Hinv50	Invasive plants cover 6-50% of AA
Hinv100	Invasive plants cover >50% of AA
Hherb	Excessive Herbivory/Pinebark Beetle/Gypsy Moth
Halgae	Nutrients dense algal mats
Hnis50	Nutrient indicator plant species cover <50% of AA
Hnis100	Nutrient indicator plant species cover >50% of AA
Htrail	Non-elevated road
Hroad	Dirt or gravel elevated road in AA
Hpave	Paved road in AA
Hydrology Category (within 40m radius of sample point)	
Wditchs	Slight Ditching; 1-3 shallow ditches (<.3m deep) in AA
Wditchm	Moderate Ditching; 3 shallow ditches in AA or 1 ditch >.3m
Wditchx	Severe Ditching; >1 ditch .3-.6 m deep or 1 ditch > .6m deep
Wchannm	Channelized stream not maintained
Wchan1	Spoil bank only one side of stream
Wchan2	Spoil bank both sides of stream
Wincision	Natural stream channel incision
Wdamdec	Weir/Dam/Road decreasing site flooding
Wimp10	Weir/Dam/Road impounding water on <10% of AA
Wimp75	Weir/Dam/Road impounding water on 10-75% of AA
Wimp100	Weir/Dam/Road impounding water on >75% of AA
Wstorm	Stormwater inputs
Wpoint	Point source (non-stormwater)
Wsed	Excessive sedimentation on wetland surface

Hydrology Category (continued)	
Wfill10	Filling or excavation on <10% of AA
Wfill75 Wfill100	Filling or excavation on 10-75% of AA Filling or excavation on >75% of AA
Wmic10	Microtopographic alterations on <10% of AA
Wmic75	Microtopographic alterations on 10-75% of AA
Wmic100	Microtopographic alterations on >75% of AA
Wsubsid	Soil subsidence or root exposure
Landscape/Buffer Category (within 100m radius outside site/AA)	
Ldevcom	Commercial or industrial development
Ldevres3	Residential development of >2 houses/acre
Ldevres2	Residential development of ≤2 houses/acre
Ldevres1	Residential development of <1 house/acre
Lrdgrav	Dirt or gravel road
Lrd2pav	2-lane paved road
Lrd4pav	≥4-lane paved road
Llndfil	Landfill or waste disposal
Lchan	Channelized streams or ditches >0.6m deep
Lag	Row crops, nursery plants, or orchards
Lagpoul	Poultry or livestock operation
Lfor	Forest harvesting within past 15 Years
Lgolf	Golf course
Lmow	Mowed area
Lmine	Sand or gravel mining operation

APPENDIX C: DERAP IWC STRESSORS AND WEIGHTS

Category/Stressor Name*	Code	Stressor Weights**		
**DERAP stressors excluded from this table are not in the rapid IWC calculation.*		Flats	Riverine	Depression
Habitat Category (within 40m radius site)				
Mowing in AA	Hmow	15	3	24
Farming activity in AA	Hfarm			
Grazing in AA	Hgraz			
Cleared land not recovering in AA	Hnorecov			
Forest age 16-30 years	Hfor16	5	4	2
≤10% of AA clear cut within 50 years	Hcc10			
Forest age 3-15 years	Hfor3	19	7	12
Forest age ≤2 years	Hfor2			
11-50% of AA clear cut within 50 years	Hcc50			
>50% of AA clear cut within 50 years	Hcc100			
Excessive Herbivory	Hherb	4	2	2
Invasive plants dominating	Hinvdom	2	20	7
Invasive plants not dominating	Hinvless	0	5	7
Chemical Defoliation	Hchem	5	9	1
Managed or Converted to Pine	Hpine			
Non-elevated road in AA	Htrail	2	2	2
Dirt or gravel elevated road in AA	Hroad			
Paved road in AA	Hpave			
Nutrient indicator species dominating AA	Hnutapp	10	12	10
Nutrients dense algal mats	Halgae			
Hydrology Category (within 40m radius site)				
Slight Ditching	Wditchs	10	0	5
Moderate Ditching	Wditchm		0	
Severe Ditching	Wditchx	17	0	
Channelized stream not maintained	Wchannm	0	13	0
Spoil bank only one side of stream	Wchan1	0	31	0
Spoil bank both sides of stream	Wchan2	0		0
Stream channel incision	Wincision	0	21	0
WeirDamRoad decreasing site flooding	Wdamdec	2	2	2
WeirDamRoad/Impounding <10%	Wimp10			
WeirDamRoad/Impounding 10-75%	Wimp75			
WeirDamRoad/Impounding >75%	Wimp100			
Stormwater Inputs	Wstorm	2	2	2
Point Source (non-stormwater)	Wpoint			
Excessive Sedimentation	Wsed			

Appendix C: DERAP IWC Stressors and Weights

Hydrology Category (continued)	Code	Flats	Riverine	Depression
Filling, excavation on <10% of AA	Wfill10	2	0	8
Filling, excavation on 10-75% of AA	Wfill75	16	11	2
Filling, excavation on >75% of AA	Wfill100			
Soil Subsidence/Root Exposure	Wsubsid	7	0	0
Microtopo alterations on <10% of AA	Wmic10			
Microtopo alteations on 10-75% of AA	Wmic75	16	11	2
Microtopo alterations on >75% of AA	Wmic100			
Buffer Category (100m radius around site)				
Development- commercial or industrial	Ldevcom	1 buffer stressor = 3	1 buffer stressor = 1	1 buffer stressor = 4
Residential >2 houses/acre	Ldevres3			
Residential ≤2 houses/acre	Ldevres2			
Residential <1 house/acre	Ldevres1			
Roads (buffer) mostly dirt or gravel	Lrdgrav			
Roads (buffer) mostly 2- lane paved	Lrd2pav	2 buffer stressors = 6	2 buffer stressors = 2	2 buffer stressors = 8
Roads (buffer) mostly 4-lane paved	Lrd4pav			
Landfill/Waste Disposal	Llndfil			
Channelized Streams/ditches >0.6m deep	Lchan			
Row crops, nursery plants, orchards	Lag			
Poultry or Livestock operation	Lagpoul			
Forest Harvesting Within Last 15 Years	Lfor	≥ 3 buffer stressors = 9	≥ 3 buffer stressors = 3	≥ 3 buffer stressors = 12
Golf Course	Lgolf			
Mowed Area	Lmow			
Sand/Gravel Operation	Lmine			
Intercept/Base Value		95	91	82
Flats IWCrapid= 95 -(∑weights(Habitat+Hydro+Buffer))				
Riverine IWCrapid= 91 -(∑weights(Habitat+Hydro+Buffer))				
Depression IWCrapid= 82 -(∑weights(Habitat+Hydro+Buffer))				

***Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.*

Appendix D-I are stored as a separate file and can be found online at Delaware Wetlands, Watershed Health Home, Mispiollion watershed.
http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Pages/WatershedHealth.aspx

This report and other watershed condition reports, assessment methods, and scoring protocols can be found on the Delaware Wetlands website:

Delaware Wetlands

Purify Provide Protect

http://de.gov/delawarewetlands